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Studies on the Spacing Density of Rice Plants

Part 1. Density effects on yield and intraspecific competition

Mikio KANDA and Yosei KAKIZAKI

(Received on September 28, 1956)

I. Introduction

On the occasion of the cultivation of plants, the spacing density and the mode of spatial hill arrangement are correlated with other enviromental factors, and their adequacy influences greatly upon yields. Accordingly, as one of the fundamental agronomical problems, many of researchers have studied how to yield most effectively by what degrees of the spacing density, on various crops or vegetables.

In relation to the intraspecific competition of plants, the past achievements concerning the spacing density and other related problems have been compiled by Clements et al[1], and the report of Kira et al[2] is a work with detailed description among other relevant literatures after Clements.

With respect to the rice culture, as is the same for other crops, as the suitability of spacing dencity, which is directly related with the productivity of grains, is an important agronomical problem, most of the agricultural experiment stations in each prefecture has made various experiments since the early works of Kikkawa[3], Shinjo[4] and Ando[5] in this country. However, as pointed by Ikeda[6] and Kira[7], most of these studies tended to limit the range of experiments due to excessive emphasis upon the practical techniques of cultivation and to be so fractional, that it is regretted that the results of their experiments showed difficulty to clarify the fundamental pricinple among the spacing density, the intraspecific competition and the yield.

Although Hayashi[7] and Hoshino[8] have made a comparatively specific investigation on the spacing density of rice plants, the quantitative interpretation of the governing law lying between yield and spacing density and the analysis of its mechanism are in considerable part dependent upon the future studies.

By accumulating individual cases which had revealed different relativities

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between yield and spacing density with various extrinsic and intrinsic factors, the authers have made the population ecological studies from the veiw point of intraspecific competetion and cooperation among the individuals of the same species to grasp the general quantitative rule lying between yield and spacing density and further to elucidate its mechanism.

The present report referred to part of the experimental results on the appearance of intraspecific competetion with the change of spacing density and its influence upon yield under the condition of quadratic arrangement of hill and of a plant a hill.

Before proceeding further the authors wish to express their hearty thanks to Professor Dr. Shigeharu Yoshida for his valuable advices and suggestions.

II. Materials and methods

The term of spacing density in this paper is defined as the number of seedlings per unit acreage planted at the transplanting time as in the conventional practice. The authors' aim in the present experiment, as is above mentioned, is to clarify the influence of changing the spacing density, viz., the changing of nunber of seedlings per *tsubo* planted at the transplanting time, upon the growth of plants and yield. In this case, there can be thought of a successive mode of hill arrangement from the nuiform distribution (determinismic or stochastic) through the aggregative distribution (colonial hill arrangement), which are expected respectively to bring about different results of the influence of spacing density. As the relativity between these modes of hill arrangement and spacing density shall be reported at another opportunity, in this paper the investigation is limited to the case of the quadratic arrangement of hill and of a plant per hill.

The experiments were conducted on the experimental design described in Table 1, in order to examine the relationship between competition and spacing density and that between yield and spacing density in respective stages of growth and different species of variety in accordance with the change of fertility levels of nitrogen. The size of plot for each treatment was fixed at one *tsubo* (about

Table 1. Treatment of experimental plots

Variety	Spacing Density per *tsubo*	Fertility level of Nitrogen	Replication
Norin-No. 1	25 plants (Distance of plants : 1.2 ′)	−N(non-nitrogen plot)	2 times
	49 plants (〃 〃 〃 0.85′)	N(2.4kg per *tan*)	
	81 plants (〃 〃 〃 0.66′)	2N(4.8kg per *tan*)	
Sekiyama Zairai	169 plants (〃 〃 〃 0.46′)	4N(9.6kg per *tan*)	
	324 plants (〃 〃 〃 0.33′)		
	676 plants (〃 〃 〃 0.23′)		
Total number of plots : 2×6×4×2=96 plots			

Note : *tsubo* -- (6′ × 6′) *tan* -- 0.245 acres

$6' \times 6'$), where careful cultural management was undertaken for the period from seeding to harvesting according to the conventional method.

According as the stage of growth advanced, the plants were picked up three times at the end of available tillering stage, the maximal tillering stage and the heading stage, then their plant height, number of tillers per hill and weight of dry matter (excluding roots) were measured. In addition, the harvested plants were subjected to the chemical analysis.

III. Experimental results

1. Influence of spacing density on plant height and number of tillers per hill

The plant height in the non-nitrogen plots became higher gradually with the increase of spacing density but it became lower contrariwise with the increase of spacing density in the plots of high spacing density more than 169 plants per *tsubo*. On the contrary, the plant height in the plots which were applied N, 2 N and 4 N respectively became higher with the increase of spacing density within the limits of spacing density in this experiment.

As the rate of increase of plant height was bigger in populations of comparatively lower density and was reduced gradually with the increase of spacing density, the curves of plant height - spacing density is characterized with the asymptotic aspect as shown in Fig. 1. Although in this figure the curves of only

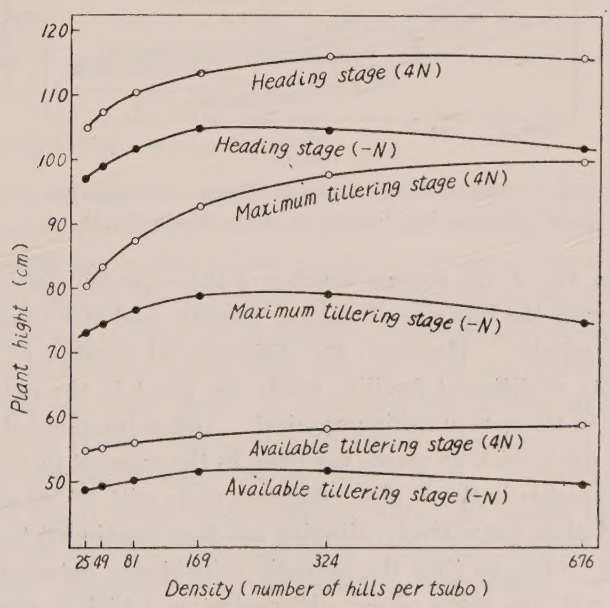

Fig. 1. Relationship between plant height and spacing density (Variety: Norin-No. 1).

none-N plot and 4 N plot were drawn, N plot and 2 N plot were to lie between these two plots.

The above-mentioned relationship between plant height and spacing density was similarly observed in Norin-No. 1 and Sekiyamazairai, thus showing no different tendency among the varieties.

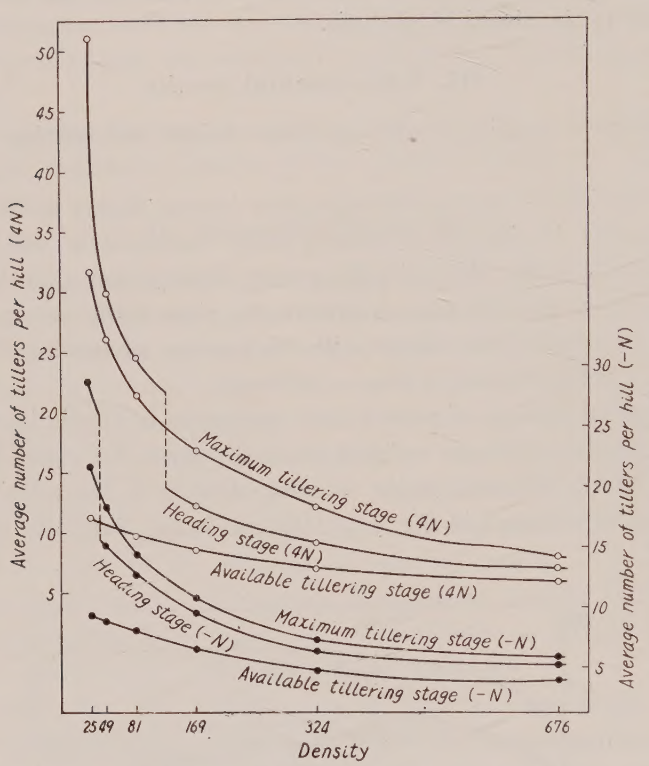

Fig. 2. Relationship between number of tillers per plant and spacing density (Variety Norin-No. 1).

As shown in Fig. 2, the average number of tillers per hill indicated an asymptotic decrease with the increase of spacing density, and this tendency was seen in both of the varieties. However, the difference of number of tillers per hill between the plots of different fertility levels was great in the case of Norin-No. 1 and was small in the case of Sekiyamazairai. And in the plots of comparatively low density (the plots with 25 plants per *tsubo* in the none-N plot, two plots with 25 plants and 45 plants in the N plot, and three plots with 25, 49 and 81 plants in the 2 N and 4 N plots respectively, tillering has been continued to the latter part of the tillering stage, so that the periodic coincidence between the maximal tillering stage and the stage of ear differentiation which is considered as the standard type in the Tohoku districts was not recognized and the time of the

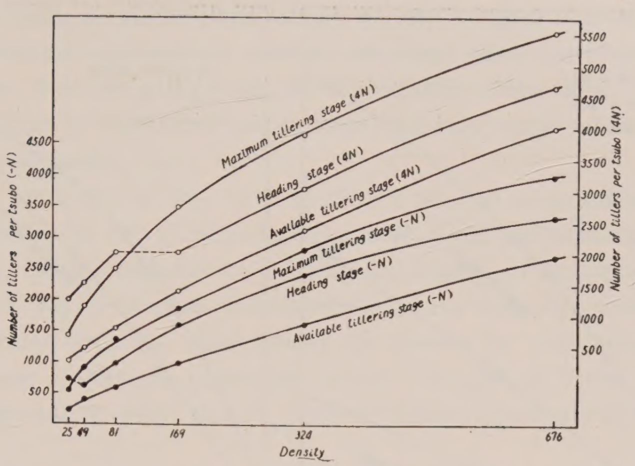

Fig. 3. Relationship between number of tillers per *tsubo* and spacing density (Variety Norin-No. 1).

maximal tillering stage was considerably delayed.

Contrary to the above-mentioned average number of tillers per hill, the total number of tillers per *tsubo* increased with the increase of spacing density, but its increase rate which was followed by the increase of population density decreased gradually according as the density became higher. Although the curves of number of tillers and spacing density in the non-N plot and 4 N plot at the respective growing stages of Norin-No. 1 are shown in Fig. 3, the case of Sekiyama-zairai showed only the difference of the absolute value, but the tendency was all the same. And N plot and 2 N plot presented an intermediate aspect between the non-N plot and 4 N plot respectively.

2. Dry weight and spacing density

In a limited acreage the quantity of individual growth becomes to decrease according as spacing density increases gradually, but the total yield per unit acreage in creased gradually to a certain extent regardless of rice plants or other crops. As no difference was seen at the beginning of transplanting in the individual weight among the plots of any spacing density subject to the present experiment, there was observed a completely linear relationship between yield and spacing density. Figs. 4 and 5 show the total dry weight per *tsubo* and the average dry weight per hill which presented the transformation from this linear relationship into the asymptotic relationship with the development of growth stage. According to the present experiment, the linear relationship between yield and spcing density was kept by the end of the available tillering stage irrespective of variety and fertility level, while the phenomenon of intraspecific competition was not obersved. Thereafter, with the advancement of development of growth, the intraspecific competition among individual plants began to take place and to strengthen

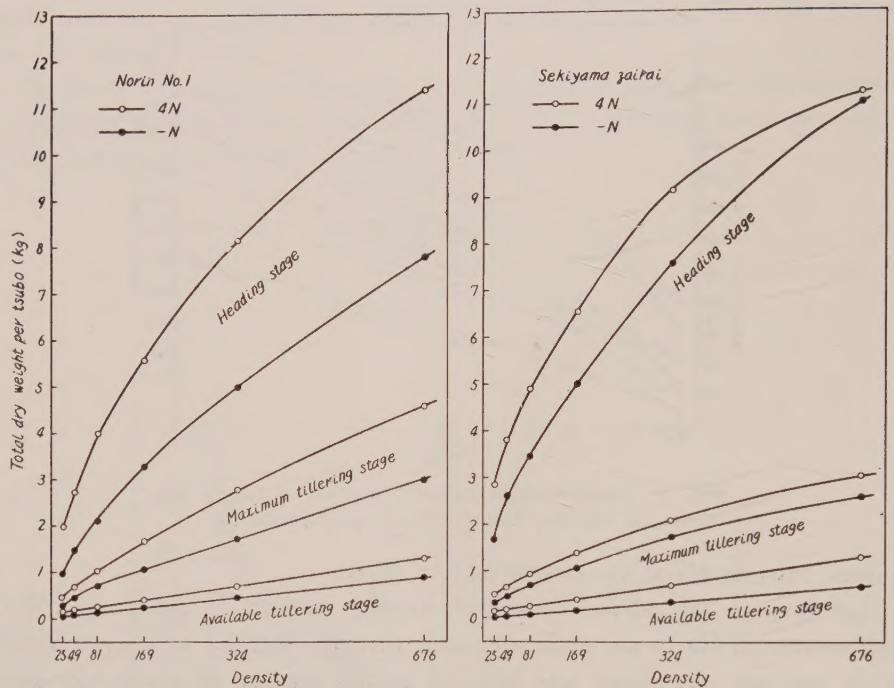

Fig. 4. Relationship between total weight of dry matter per *tsubo* and spacing dentisty

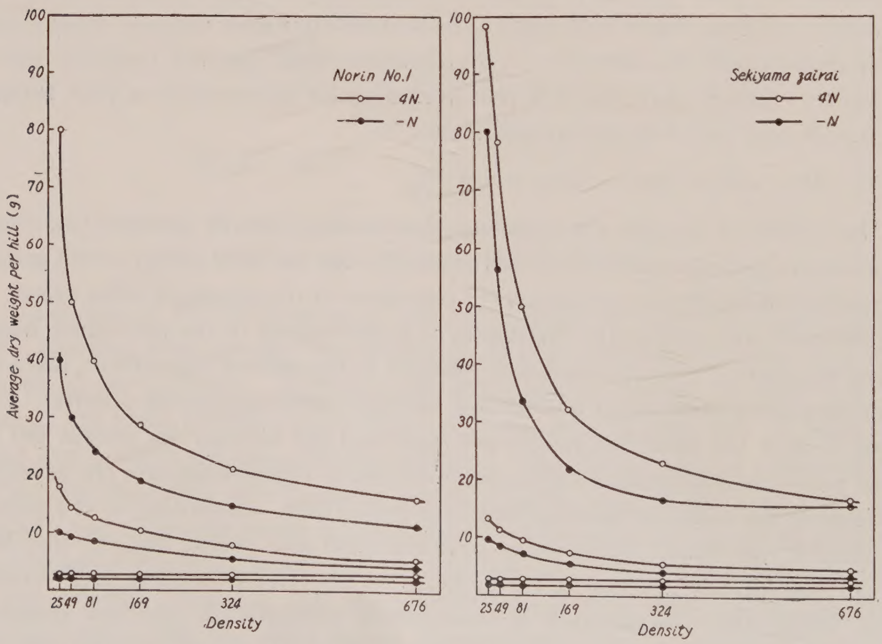

Fig. 5. Relationship between average dry weight per *tsubo* and spacing density.

the asymptotic tendency in the plots of high density. Against the fact that there was seen the mutual intervention among individual plants in plant height and number of tillers from the early stage, the intraspecific competition in dry weight was not recognized by the end of the available tillering stage. This is to be considered as an interesting fact.

As shown evidently in Fig. 4, Norin-No. 1 showed a considerable increase of dry weight with the elevation of fertility level, while Sekiyamazairai indicated a comparatively small difference of yield by the change of fertility level.

Fig. 6. and Fig. 7 showed the transition of the total dry weight per *tsubo* and per individual with the development of growth at respective stages on the plot of rare density (25 plants per *tsubo*), the plot of dense density (676 plants per *tsubo*) and 81-plant plot of mediocre density (approximately equivalent

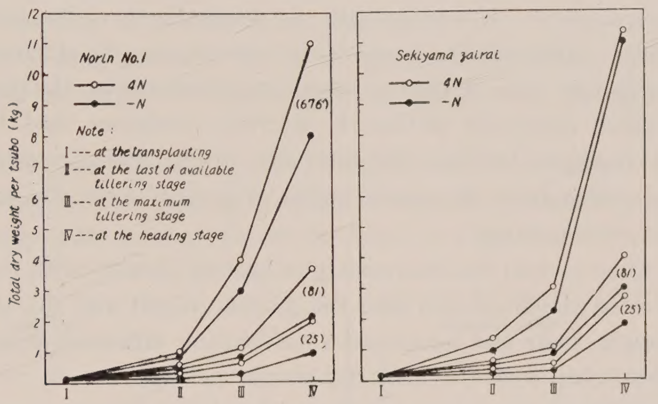

Fig. 6. Increse of the dry weight per tsubo with the developmental growth.

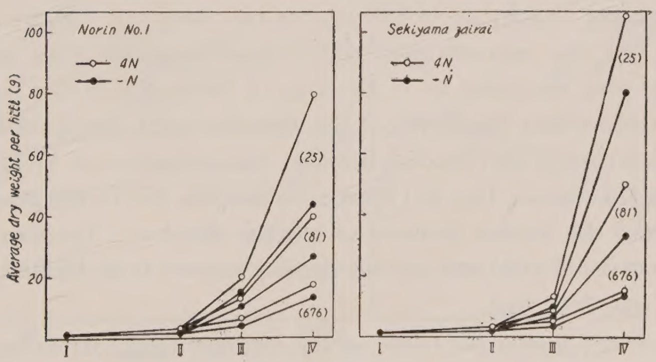

Fig. 7. Increase of the average dry weight of individuals with develpmental growth.

to the farmers conventional density under the condition of a plant per hill) in the two cases of the application of N and 4 N. As stated already, the difference of dry weight due to the spacing density was not recognized by the end of the available tillering stage, but thereafter the individual dry weight became to increase with the development of growth and the increase rate became greater in the plot of lower density with the elevation of fertility level. As for the total yield per *tsubo*, the decrease of the increasing rate of the individual dry weight did not become so significant as to show the direct proportion to the increase of spacing density, therefore the yield per unit acreage became greater in the plot of higher density.

3. Panicle weight, straw weight and spacing density

The relationship between the total dry weight per *tsubo* and the spacing density became to change from the liner relationship at the beginning of plantation into the asymptotic relationship with the development of the growing stage, as stated already. Although the curve of the total dry weight of harvested plants and the spacing density showed also the asymptotic relationship, the tendency took up the form which expedited farther the previous condition, and the presence of a consistent tendency between the total dry weight and the spacing density was recognized throughout the entire stages of growth from the transplanting stage to the harvesting stage.

However, when viewed the relationship of spacing density with the total dry weight of harvested plants divided into the panicle weight and the straw weight as its partial weight, there was recognized a considerable difference from the above-mentioned relationship with the total dry weight per hill.

The increase of the dry straw weight resultant from the increase of spacing density was more conspicuous than the case of the total dry weight. The relationship between yield and spacing density of Norin-No. 1 showed a convexly asymptotic curve due to the gradual decrease of the increasing rate of yield with the increase of spacing density as in the case of the total dry weight per hill. On the contrary, in the non-nitrogen polt of Sekiyamazairai (the polts of other fertility levels were the same as in the case of Norin-No. 1) the increasing rate of yield per *tsubo* within the limits of the 169 plant plot was accordant with the increase or decrease of the spacing density, and its curves of yield and spacing density showed a concave line and drew a convex line due to the gradual decrease of yield against the further increase of spacing density. In short, the critical point of the curves of yield and spacing density seemed to be located in the neighbourhood of 169-plant plot.

The panicle dry weight per *tsubo*, on the contrary to the straw weight, showed a conspicuously small increase of yield with the increase of spacing density as compared with the case of total weight of dry matter per hill. In the case of

Norin-No. 1, its increase curve indicated the same proportional increase as the total palnt weight and straw weight, and the difference of fertility level of nitrogen caused only the change of levels of productivity without varying the form of the curves, and the curves of yield and spacing density in the non-nitrogen plot and nitrogen-drich plot drew approximately a parallel line.

With a conspicuous difference from Norin-No. 1, in the case of Sekiyamazairai the panicle weight per *tsubo* increased with the increase of density by 81 plants per *tsubo* (by 49 plants in 4 N plot), but it decreased rapidly thereafter with the furthernace of its increase in the denser plots and showed a greater decrease in the N-rich plots. while the yield became lowered in proportion to the abundance of nitrogen in the plots as compared with the non-nitrogen plot. And the approximate values of yield at the maximal point of the curves of yield and spacing density irrespective of the difference of fertility levels of nitrogen were far from being elucidated as the accidental coincidence by the present experiment. but this may be an interesting finding.

The relationship between the total plant weight, panicle weight and straw weight of harvested plants and the spacing density may be fererred to Figs. 8 and 9.

The rate of panicle weight (panicle weight/total plant weight is called with this term hereafter) is important for showing the efficiency of grain productivity, and its relationship with spacing density is shown in Fig. 10.

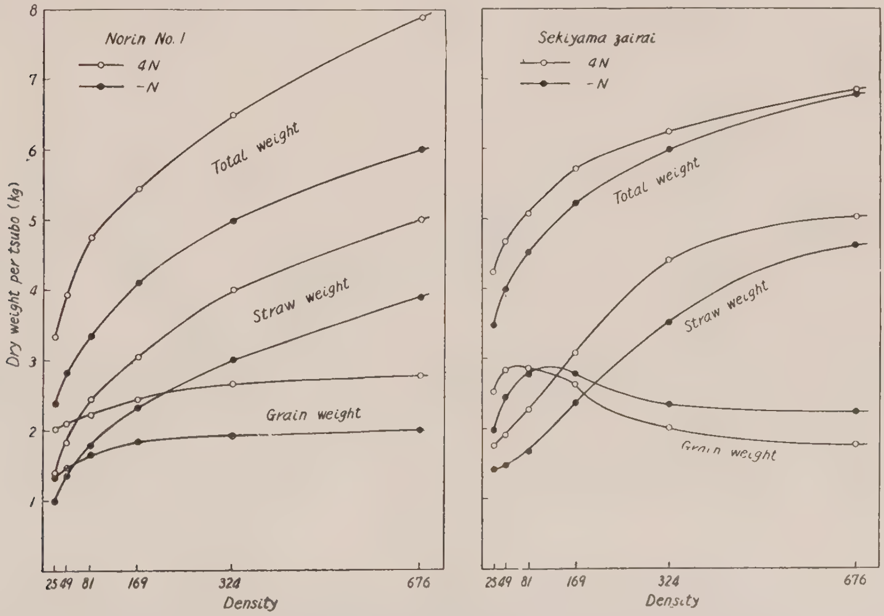

Fig. 8. Relationships between total weight of dry matter per *tsubo* straw weight, panicle weight and spacing density.

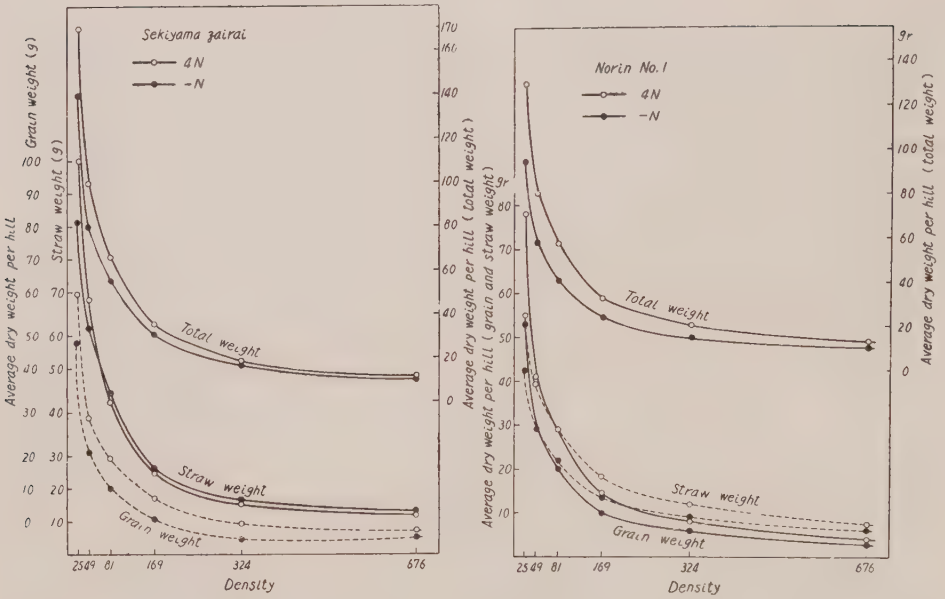

Fig. 9. Relationships between the total weight of dry matter per individual, straw weight, panicle weight and spacing density.

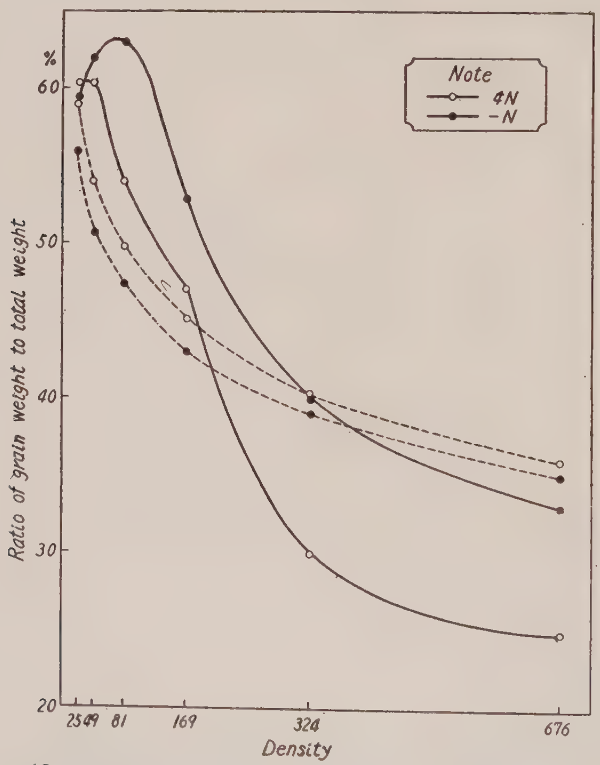

Fig. 10. Relationship between the ratio of panicle weight (panicle weight/total weight) and spacing density (...... line indicate Norin-No. 1, —— line indicates Sekiyama-Zaieai).

In the case of Norin-No. 1, the increase of density invited all the time the decrease of rate of panicle weight, and the curves of yield and spacing density indicated a descending curve in the form of concavely asymptotic line. And the rate of panicle weight became to increase with the elevation of fertility level of nitrogen under the same density condition. Contrary to this, in the case of Sekiyamazairai, the curves differenciaitted from the case of Norin-No. 1 and showed the following characteristics, with the conversion from rare density to dense density : (1). The rate of panicle weight increased to reach the maximal point with the increase of spacing density and (2). thereafter it began to decrease with the furthernace of denseness in population of plants. The areas subjected to the decrease of rate of panicle weight can be classified into the plots of a comparatively low decreasing rate at the begining and the plots which showed thereafter a rapid increases of the decreasing rate. Excepting the most rarely populated plot with 25 plants per *tsubo*, in other plots the lower the fertility level of nitrogen became the more the rate of panicle weight increased, showing a remarkable contrast to the case of Norin-No. 1. As evidently shown in Fig. 10, the rate of panicle weight of Norin-No. 1 was considerably higher up to the plot with 169 plants per *tsubo* than variety Sekiyamazairai, but that of the latter was higher reversely in the plots of denser density than the former.

It is of great interest that the difference of the rate of panicle weight between the two varieties of rice plant represents their characteristic for cultivation. However, it is difficult to determine whether such difference is attributable to the essential peculiarlity of their own or their difference of phases.

IV. Discussion

It has been generally known that the amount of the average individual growth becomes to decrease gradually with the increase of spacing density under a limited enviromental capacity. Such a case as to give a minus influence upon another individual by the presence of one individual is called "competition", while a case in which the maximum amount of growth in a plant is presented in a certain high density, as is shown comparatively early at the beginning of the growing stage in some plants ,and the growth of the individual becomes oppressed in the case of lower density than before is termed "cooperation". However, although the definition of "competition" or "cooperation" is still not clear phenomenally and, moreover, the content of these terms are differentiated by the users, the authors have used the terms in a broad sense according to the conventional usage.

Various measurable attributes may be given for the measurement of intensity of the action of mutual intervention, and the phenomena of competition are considered to indicate the peculiarlities of individual plants. Taking up the

plant height, number of tillers and dry weight (total plant weight, panicle weight and straw weight) which are related most closely with productivity of rice plants, the authors have pursued their quantitative relationship with the spacing density, stages of growth and fertility levels of nitrogen.

As the abnormal chracteristic of the relationship between plant height and spacing density, it was observed that the furtherance of density became to increase plant height gradually in the case of abundant nitrogen supply and the medium spacing density brought about the maximal plant height in the case of the low ferility level of nitrogen, while the further increase of spacing density led a reduce plant height gradually. Thus, although the tendency differed somewhat with the difference of fertility level of nitrogen, it is significant that in all the cases there was observed the cooperative phenomenon among the individuals in relation to plant height.

As for the increasing tendency of plant height with the increase of spacing density, its specific significance or its generative mechanism could not be elucidated by the present experiment. It is ,therefore, still dubious to regard the above-mentioned tendency as the cooperative phenomenon. This respect shall be reffered to later.

Although the decrease of number of tillers per plant with the increase of spacing density was already mentioned in the chapter of the experimental results, this tendency began to reveal at the begining of the growing stage and became more and more conspicuous with the advancement of the growing stage. And tillering was continued even after the heading stage in the plots of extremely rare density, and the maximal tillering stage was retarded considerably. However, such a tendency toward the abnormal tillering became impossible to be seen in the plots of dense density more than 169 plants per *tsubo*.

The plant height and the number of tillers per plant revealed the influence of spacing density from the begining of the growing stage such as to show the elongation of plant height and the gradual decrease of the average number of tillers per hill with the furtherance of density, while the influence of spacing density was not revealed on the dry weight per plant in the availabe tillering stage ,and there was not seen any relationship of competition among the individuals as the curves of dry weight and spacing density showed a straight line. Thus, to give no influence of spacing density upon the amonut of individual growth as "mass" is considered to be due to the action of mutual aid between the plant height and the number of tillers per plant, and the elongation of plant height resultant from the increase of spacing density may be interpreted as an expression of the cooperative function among the individuals.

From the end of the available tillering stage, the relationship between the dry weight per *tsubo* and the spacing density was intensified gradually the asymptotic tendency with the advancement of growth, and the cooperative relationship

among the individuals at the begining of the growing stage was replaced gradually with the relationship of more intensive competition.

The inter-relationship among the growing stage, the dry weight per *tsubo* and the spacing density, as stated above, kept an extremely beautiful line in group, which began with a linear relationship between the seedling weight at the begining of the growing stage and the spacing density with the initiation of the competitive phenomenon merely in the plots of extremely dense density, and thereafter became to reveal the competition even in the plots of rare density with the furtherance of the growing process. Donald[9] reported that the competition became particularly so dominant in the plots of dense density with the advancement of growth as to lead the growth of the individual (separately from its development) to the static condition, and the yield per unit acreage would take a certain value irrelevant to the spacing density under the maximal condition. Furthermore, he confirmed the relationship of the yield per individual to be in inverse proportion to the spacing density under such a maximal condition by carrying out his experiment on herbage. Kira et al[2] recognized the same phenomenon on vegetables, and have advocated the existence law of constant yield under the maximal condition.

Such an extreme relationship was not observed within the spacing density and fertility conditions applied for the authors' experiment, but it was considered in view of the transformation of the curves of yield and spacing density that the similar tendency may be observable in the plots of denser spacing density (if the ocurrence of extraordinary states of affairs by lodgings and other factors is avoidable).

As for the above-mentioned relationship between yield and spacing density, many attempts have been made to regularlize quantatively with formulae and various formulations on crops, lumbers and others have been proposed.

Keller and Li[10] applied the relationship between the yield per plant and the number of veins per plant in hops with the parabolic formula, and willcox[11] reported that the formula of Mitscherlich

$$y = A[1-\mathrm{ecp}\,(-cx)]$$

(y: yield of the individual, A: the maximum yield of the individual, x: spacing density, but the distance between plants).

would be most suitable to the data. However, Donald[9] suggested that the formula of Mitscherlich could not be applied to the plot of mediocre density.

As the most suitable formula to many experimental results, Kira et al[2] have adovaocated the following hyperbolic formula

$$wd^a = K \tag{1}$$

(w: the average individual dry weight, b: spacing density, but the number of individuals per 1m^2, a and K are constants affixed by the stage of growth).

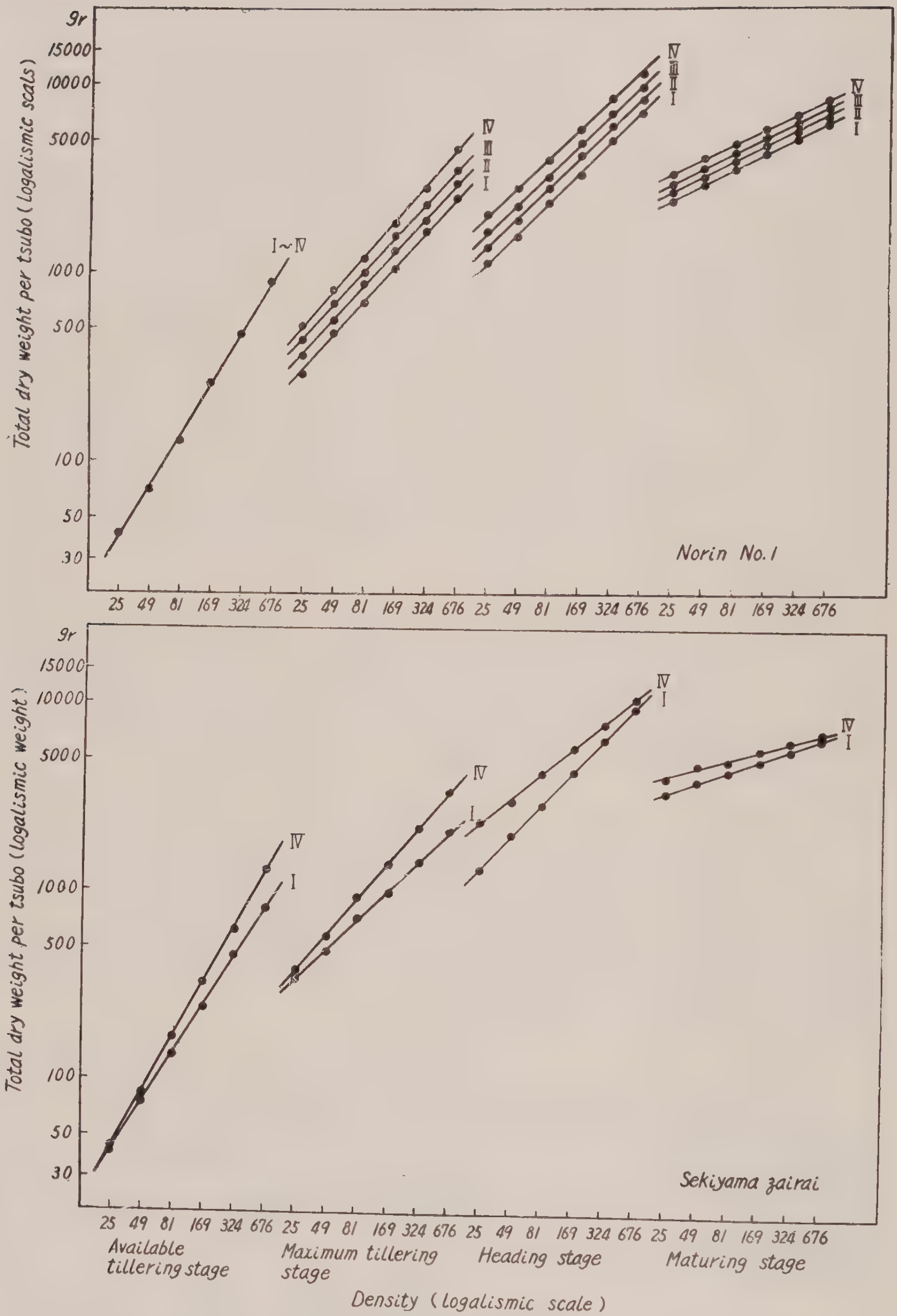

Fig. 11. Relationship between total weight of dry matter per hill and spacing density (by logarithmic scale transformatien).

and termed this the law of competition — density effect. Furthermore, they[12] succeeded in formulating the following hyperbolic formula

$$w = 1/A\rho + B \qquad (2)$$

(w:the average individual weight, ρ: spacing density. They termed this formula the reciprocal law of competition density effect).

as the formula for the higher approximation, on the basis that the growing curve of plants indicates the logistic curve.

As shown in Fig. 11, formula (1) can apply fairly well to the total wight of dry matter resultant from the authors' expreiment regardless of the stages of growth and fertility levels of nitrogen, and the law of yield- density effect adovocated by kira et al (2) is considered to be applicable to the case of rice plants. Moreover, as the similar relationship was constituted between yield and fertility level of nitrogen was effected as shown evidently in Fig. 12, the relationship between yield and spacing density and that between yield and fertility level of nitrogen are considered to be governed in appearance at least by the abovementioned law.

Subsequently, in case the total weight of dry matter was divided into its component elements of the straw weight and the panicle weight, the law of Kira et al seemed not necessarily applicabe in view of the relationship between these weight and the spacing density.

As for the panicle weight particularly, the panicle weight of Sekiyamazairai per *tsubo* showed the maximal point between 49-81 plants in the 4 N plot and between 81-169 plants in the non-nitrogen plot respectively, thereafter the denser the spacing density became the more the panicle weight per *tsubo* decreased. This respect indicated a remarkable

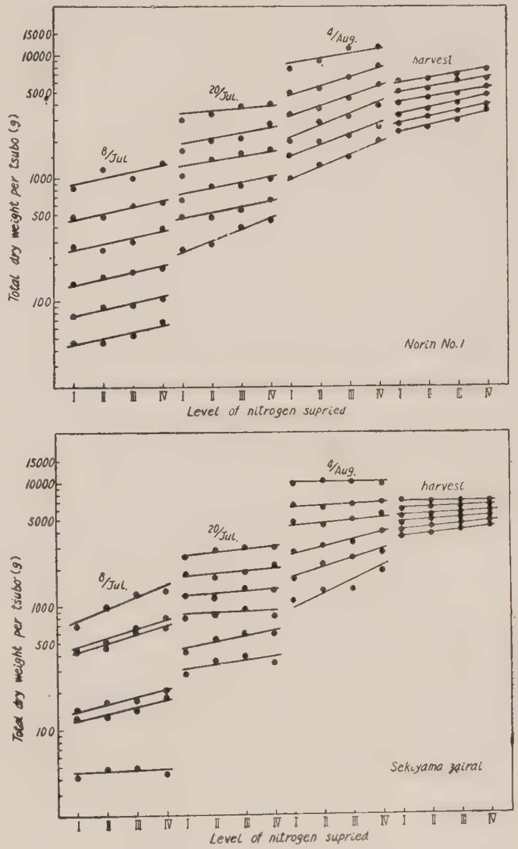

Fig. 12. Relationship between total weight of dry matter per tsubo and fertility level of nitrogen (by logarithmic scale transformation).

contrast to Norin-N.o 1 which showed the gradual increase of the panicle weight per *tsubo* with the increase of density, As the variety of Sekiyamazairai tended to show a somewhat lodging tendency with the increase of ferility level of nitrogen in the plot of dense spacing density more than 169 plants per *tsubo* after heading, the above-mentioned movement of the panicle weight may be inferred as the abnormal phenomenon due to lodging. Meanwhile, Ikeda[6] recognized the similar tendency in the panicle weight of wheat per *tsubo*, and explained the reason to the effect that the decrease of the average panicle weight and the increase of the panicle weight per *tsubo* with the increase of spacing density were suspended to function the action of mutal aid in the plots of dense spacing density which exceeded a certain extent.

Provided that the phenomenon which showed that the grain yield attained the mximum in the plots of a certain density and contrariwise decreased with the increase of density beyond it is construed not as the abnormal conditions such as lodging but as the common phenomenon between yield and spacing density of rice and wheat plants, it is expected that Norin-No. 1 in the areas of extremely dense spacing density and high fertility level will give rise to the similar tendency to the case of Sekiyamazairai. Consequently, the difference between Norin-No. 1 and Sekiyamazairai on the relationship between yield and spacing density is considered not due to the essential difference between the two varieties but to the transformation of physiognomical aspects.

Although the law of yield — density effect advocated by Kira et al[2] seemed to effect on the total weight of dry matter per hill with the relationship between yield and spacing density, it is observed that this law does not necessarily be applicabe to the straw weight and panicle weight which are the partial weight of harvested plants. From this respect, the relationship between the distribution ratio of panicle weight and straw weight from the total plant weight and the spacing density is considered to accord with the formula

$$y = bx^{\alpha}$$

(where x and y are the respective partial weigth and α and d are constants respectively, but signifies the reciprocal growth ratio of x and y. cf. Huxley (13) and Pearsall (14)).

which is the law in allometry of the relationship between pertial weights. Fig. 13 indicates clearly the above-mentioned relations.

From the practical point of view, the relationship among the panicle weight, the straw weight and the spacing density is more important than the total yield of plants. Therefore, to clarify the quantative rule governing these relations is desired strongly.

Putting aside the case of Sekiyamazairai on account of its extraordinary status, the relationship between the panicle and straw weights and the spacing density (rather specifically in the areas of comparatively rare density which

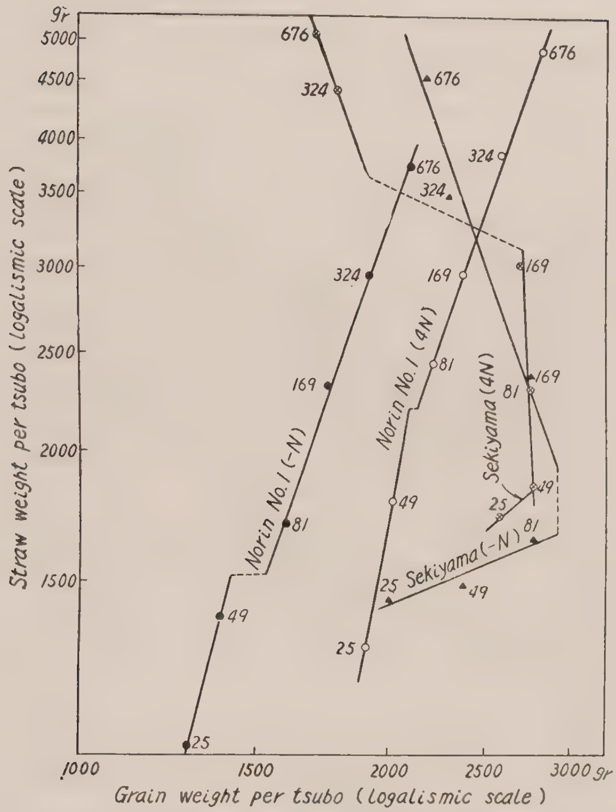

Fig. 13. Relationship between panicle weight and straw weight (Numbers in the figure indicate spacing density).

increased the yield per *tsubo* with the furtherance of density) in the case of Norin-No. 1. may be applied to the following orthogonal hyperbolic experimental formula

$$Y = A' + B'x/A + Bx$$

(Y: yield per tsubo, x: Number of individuals per *tsubo*, A, B, A′, B′: constants).

according to the data of the present experiment (cf. Fig. 14). However, it should be examined further that the formula has defects in determining the coefficients and whether it is applicable to all the cases in the areas of spacing density within the limits to lead yielding to the maximal point.

V. Summary

The authors made a series of experiments to clarify the change of relationship between yield and spacing density according to various external and internal factors from the population ecological viewpoint of intraspecific competition and

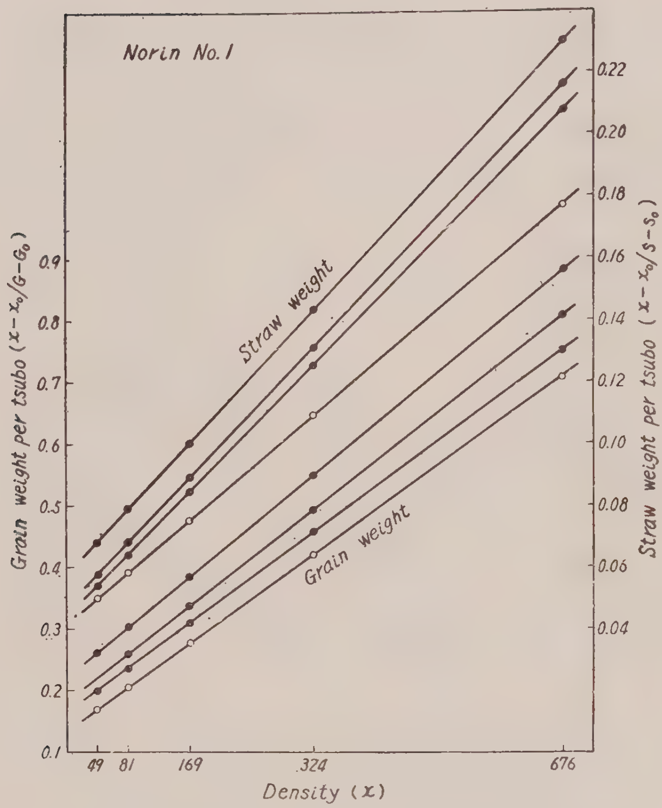

Fig. 14. Relationships between panicle weight, straw weight and spacing density.

cooperation among the individual plants of the same species, and at the same time to get hold of the general applicable formula on the relationship between them and further to lead a clue for the explanation of its mechanism.

The present report referred to part of the experimental results on the ocurrence of the mutual intervention among individual plants and its effect upon yielding under the condition of quadratic arrangement of hill and a plant per hill.

plant height and spacing density :

1) The height of plants showed the maximal point at the 169-plant plot in the non-nitrogen plots, and it became lower in accordance with the distance from this point thereabout.

2) The height of plants increased proportionally in the nitrogen-supplied polts applied N, 2 N and 4 N with the increase of density.

3) There was seen no difference of the above-mentioned tendency among the varieties subjected to the present experiment.

4) The tendency of elongation of plant height with the increase of density

is considered as an expression of the cooperative function among the individual plants.

5) The mutual intervention of individual plants in plant height was seen from the comparatively early stage of growth.

Number of tillers per hill and spacing density :

6) The average number of tillers per hill decreased gradually in the asymptotic form with the increase of density.

7) Intraspecific competition among individual plants in the number of tillers per hill revealed from the comparatively early stage of growth.

8) The decreasing tendency of the average number of tillers per hill resultant from the increase of density showed no difference between varieties as well as among the plots of different fertility levels of nitrogen.

9) The total number of tillers per hill increased asymptotically with the increase of density.

10) The average weight of dry matter was not affected by the spacing density by the end of the available tillering stage.

11). The relationship between dry weight per *tsubo* and spacing density tended to intensify the asymptotic tendency gradually from the preceding linear relationship, and the cooperative relationship among the individual plants at the begining of the growing stage became to be replaced with the competitive relationship.

12) The interrelationship among dry weight per *tsubo*, stage of growth and spacing density coincided with the law of yield and density effect which has been advocated by Kira et al.

Panicle weight, straw weight and spacing density :

13) The straw weight per *tsubo* increased asymptotically with the increase of spacing density. And the tendency was by far greater than the case of the total weight of dry matter per hill. The variety of Sekiyamazairai was remarkable in the increase of straw weight with density more than the mediocre degree, as compared with the case of Norin-No. 1.

14) In the case of Norin-No.1 the panicle weight per *tsubo* increased gradually with the increase of density, while in the case of Sekiyamazairai its maximal point was indicated in the area of mediocre density.

15) Kira's law for the effect of density on yield is considered not to be applicable farily well to the panicle and straw weights.

16) In the case of Norin-No. 1, the orthogonal hyperbolic experimental formula $Y=A'+Bx'/A+Bx$ is supposed in the present experiment to give a good fit to the relationship between the panicle and straw weights and the spacing density.

17) It should be studied further whether the above-mentioned formula

is applicable to all the cases in the areas of such limited spacing density as to show the maximal yield.

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Studies on the *Helminthosporium* Leaf Blight of Rice Plant

Part 1. On the outbreak of diseases in a humus-rich muck paddy field

Masayuki SAKAMOTO, Katsumi SATO, Sukemoto KUDO, and Teruko ŌMATSUZAWA

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I. Introduction

With the advancement of works for improvement of paddy field of low productivity, the *Helminthosporium* leaf blight, a well-known disease of rice plant, has been attracting special attention of many workers in various fields of agricultural science as a particular disease accompanied by the "Akiochi" phenomena.

The "Akiochi" phenomena in the west-southern warm districts in this country have been attributed to the physiological disorders of rice plants grown in degradaded paddy fields, as the results of severe rottening of plant roots and unbalanced absorption of nutritional elements caused by unfavorable effect of hydrogen sulfide emitted.[1)2)] Accordingly, particular incidence of the leaf blight in "Akiochi" paddy fields is considered to be connected with such physiological disorders of the plants. For instance, Yokogi *et al.*[3)] reported the present disease in those paddy fields which produced abundant rotten roots. Baba[4)5)] recognized its increase by the treatment of hydrogen sulfide on plant roots; furthermore, he pointed out its close relationship to the physiological conditions of rice plant grown in the "Akiochi" or ill-drained paddy fields paying attention to potassium-nitrogen ratio and particularly to deficient manganese content in plant bodies.

Since 1953 the authors with other members of the Institute have been studying on the low productive paddy fields in the Tohoku District. The paddy field under investigation is a humus-rich, ill-drained one, and it is quite different in soil constitution and its processes inducing low productivity from those in the west-southern districts above mentioned, although it is called similarly the "Akiochi" paddy field.[6)7)] It is a common phenomenon, that severe outbreak of the *Helminthosporium* leaf blight is usually observed in both fields. Moreover, the

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* The 171st report of the Institute for Agricultural Research, Tohoku University.

occurrence of the leaf blast, caused by *Piricularia oryzae*, is seen frequently in our field depending upon the climatic conditions at the early stages of plant growth. Also the stem rot or sclerotial disease by *Helminthosporium sigmoideum* var. *irregulare* usually occurs.

There are certain contrasting features between the incidence of the leaf blight and the leaf blast, in spite of their close resemblance in the manner of dissemination and the process of infection : for instance, with regard to incidence on leaves of rice plants, the former occurs remarkably at later stages of plant growth, whereas the latter rather at earlier stages. There is also recognized a reversal tendency in the influence of nitrogenous fertilizer on the severity of incidence. As a whole, it would be considered that the former takes an endemic character and the latter an epidemic one. These findings may suggest that there should be important differences in their behaviors determining the disseminating potentialities such as a readiness of abundant spore formation on lesions or of floating in air on the one hand, and also in the reactions of host plant to infection conditioned by the pathological and physiological characteristics of the respective pathogens on the other.

Thus, to clarify the reasons for particular incidence of the blight disease in a humus-rich paddy field, it is essential to investigate the manner of propagation and dissemination of the pathogen in the natural field and the influence of environmental conditions on these characters. At the same time, it is also necessary to know what variations in reaction picture of a host-tissue to the invading pathogen would be induced due to different varieties or by different physiological conditions of a host plant, because ,as will be described later, conidial formation requisite for the continuity of infection-chain can be exclusively found on the blight lesions of definite types. To clarify these problems it may be most effective to investigate comparatively on two different pathogens which show contrasting behaviors to an identical host plant, such as the leaf blight and leaf blast fungi.

The present investigation was made to know the fluctuation through a growing period in the outbreak of the leaf blight, the leaf blast, and the stem rot diseases of rice plants grown on a muck paddy field at Yamoto-machi, Miyagi Prefecture in 1955. In addition, certain findings concerning the natural incidence of the leaf blight are also given.

The authors express their appreciation to members of the research group engaged in the "studies on muck paddy fields" for their cooperation and for many helpful discussions, and also to Assistant Prof. I. Goto of the Faculty of Agriculture, Yamagata University, for contributing the culture of the leaf blight fungus used to this study.

II. Investigations on Natural Infection

1. Experimental field and culture of rice plants

The paddy field used in the present experiment is a humus-rich, muck paddy field of low productivity and located at Yamoto-machi, Monoo County, Miyagi Prefecture. It has been used as the experimental field for the research group of this Institute since 1953. It has extremely high contents of humus and nitrogen, and considerably emitts hydrogen sulfide. Yamane *et al.*[8] reported the characters of this pdddy soil in detail. There are seen usually dominant occurrences of the leaf blight, leaf blast and stem rot diseases.

Sowing : April 22, 1955 ; transplantation : June 7, 3 plants per hill and 75 hills per tsubo (about 36 square feet). Manure : 37.5 kg of ammonium sulfate, 47.9 kg of superphosphate of lime and 15 kg of potassium chloride per tan (0.2446 acre) were applied to the control plot as the basic dressing ; in twice nitrogen plots ammonium sulfate was increased to 75 kg. Three varieties of rice plant, viz., Norin 16, Norin 21, and Moko-ine, were used.

2. Climatic conditions

In 1955, the growth of rice plant was fairly good owing to the favorable weather conditions during the crop season. The leaf blight occurred severely, and the leaf blast and the stem rot occurred considerably. On the contrary, in 1954, plant growth was extremely bad under cool and cloudy weather conditions, but the occurrences of the diseases were not appreciable.

Fig. 1. illustrates the average atmospheric temperatures, insolation hours and rainfalls during the crop seasons in both years, according to the meteorological data presented by the Ishinomaki Meteorological Observatory about 10 kilometers east of Yamoto-machi. As shown in the figure, it was characteristics of the year

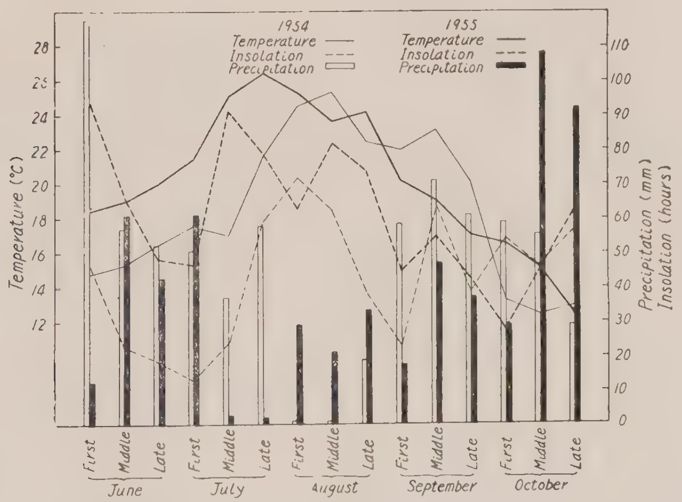

Fig. 1. Variations in average temperature, amount of precipitation, and insolation hours in each ten-days' period during the crop seasons in 1954 and 1955.

1955 that, for the first half period of plant growth, the average temperature was higher and the insolation hours were far longer than those in the preceding year.

3. Occurrences of the diseases

i) Method for investigation. *Leaf blight*: Evaluation of infection degrees has been mostly based on the number of lesions per leaf or sometimes on that with reference to their sizes; and, recently, the types of lesions, classified in view of their pathohistological distinctions, are being considered as an important criterion.[9][10] However, the present investigation was made on the number of lesions, more than 0.6 mm in diameter, per leaf at definite intervals from mid July to early September. Taking 5 individuals at random from each experimental plot, the number of lesions appearing on every leaf attached to the main and sub-main haulms (5 haulms per hill) was counted. The leaf position was numbered downward, taking the flag leaf as the first one. The number of lesions per leaf was divided into 7 classes: namely, 0,1–10, 11–25, 26–50. 51–75, 76–100, and numbers more than 100. Comparison of infection degrees among leaves was made by percentages of the leaves belonging to each class against the total number of examined leaves in the same position of a haulm.

Leaf blast and *stem rot*: As the occurrences of the leaf blast and the stem rot were far less than that of the leaf blight, their infection degrees were indicated by the number of lesions per hill.

The sampling dates of experimental materials and the growth stages of rice plants are shown in Table 1. The growth of Norin 16 was somewhat earlier than that of Norin 21, and in 2 N plots every variety delayed in its development as compared with that in the control plots.

Table 1. Sampling date and growth stage of rice plant

No. of investigation	Sampling date	Growth stage of rice plant	
		Norin 21 variety	Moko-ine variety
1	July 14	Tillering stage	Primordial stage
2	18		
3	21	Primordial stage	Internodal elongation stage
4	27		Head-bearing stage
5	Aug. 2	Internodal elongation stage	Heading stage
6	9	Head-bearing stage	Milk-ripening stage
7	18	Heading stage	
8	31	Milk-ripening stage	
9	Sept. 2		

4. Results of investigations

Occurrences of the diseases and their changes through the course of plant growth in a humus-rich paddy field are given in Tables 2 and 3.

Leaf blight: As shown in Table 2, the number of lesions increased with the advancing growth of a plant in all varieties. They were abundant in the

Table 2. Variations in th

Date of investigation	Class of number of lesions per leaf	Nôrin 16															
		N									2N						
		Leaf position									Leaf position						
		9	8	7	6	5	4	3	2	1	9	8	7	6	5	4	3
July 14	0	17	26	32	80	92					75	61	52	64	96		
	1～10	83	70	68	20	8					25	39	48	36	4		
	11～25		4														
	26～50																
18	0			21	26	76	88							27	80	100	
	1～10			43	74	24	12					60	73	73	13		
	11～25			36								40	27		7		
21	0					24	84	100					7	8	28	76	10
	1～10				33	64	16					40	29	68	60	24	
	11～25					8						60	57	16	8		
	26～50				33	4							7	4	4		
	51～75				33									4			
27	0					8	36	100	100					6	4	24	84
	1～10			23	33	58	64						63	56	64	52	16
	11～25		50	8	38	13							38	33	28	16	
	26～50		50	46	19	17								6	4	0	
	51～75			23	10	0										4	
	76～100					5											
	> 100																
August 2	0					5	4	48	96	100						16	48
	1～10				66	55	76	52	4					50	63	52	52
	11～25					32	8							50	21	32	
	26～50				33	5	12								17		
	51～75					5											
	76～100																
	> 100																
9	0					18	16	36	60	88							
	1～10					71	52	64	40	12						36	80
	11～25					6	28								22	32	12
	26～50					6	4								22	28	8
	51～75														44	4	
	76～100														0		
	> 100														11		
18	0						46	12	40	80							
	1～10					50	36	72	60	20						14	17
	11～25					50	18	16								14	50
	26～50															29	21
	51～75															43	13
	76～100																
31	0								4	40							
	1～10							6	75	56							
	11～25							60	13	4							8
	26～50							35	8								8
	51～75															100	23
	76～100																23
	> 100																38

e number of the blight lesions per leaf due to different growth stages and different leaf positions. Ex

			Nôrin 21																	
			N									2N								
			Leaf position									Leaf position								
	2	1	9	8	7	6	5	4	3	2	1	9	8	7	6	5	4	3	2	1
			0 100	13 65 17 4	36 52 12	72 28	100					0 100	9 91	48 52	88 12	96 4				
				67 33	30 55 15	60 40	95 5	100					50 50	18 76 6	36 64	74 26	0			
0					33 33 33	30 35 25 5 5	4 84 8 4	68 32	88 12	100			100	8 33 33 17 8	23 55 18 4	30 65 5	88 12	100		
	96 4				44 11 11 33	5 38 29 19 10	12 56 16 16	52 40 4 0 0 4	84 16	100			100	8 38 46 8	5 33 33 19 0 5 5	0 83 13 4	32 56 8 4	88 12	100	
	64 36	83 17			100	14 64 14 7	10 60 20 10	36 56 8	84 16	84 16	100			100	22 44 33	6 53 18 18 6	12 52 12 16 4 4 0	36 46	84 16	100
	32 68	88 12					25 25 25 17 8 0	42 16 16 16 0 11	5 90 0 5	50 50	90 10				33 33 33	8 46 23 15 8	8 46 17 8 4 8 8	12 80 8	28 72	72 28
	4 88 4 4	32 64 4					100	12 29 18 24 18	8 76 4 12	40 52 8	80 20					0 0 0 100	5 33 57 0 5	24 32 44	84 16	56 44
	4 38 13 33 4 8	72 20 4 4					100	67 33	47 37 16	8 83 8	25 75						100	44 25 6 25	28 28 40 4	8 48 28 16

Date of investigation
July 14
18
21
27
August 2
9

planation in text.

Class of number of lesions per leaf	Môko-ine																	
	N									2N								
	Leaf position									Leaf position								
	9	8	7	6	5	4	3	2	1	9	8	7	6	5	4	3	2	1
0				5	65						44	84	28	88				
1∼10	50	22	5	65	35					50	52	8	68	12				
11∼25	25	22	30	30						50	4	8	4					
26∼50	25	44	50															
51∼75		6																
76∼100		6	10															
> 100			5															
0					10	90								15	90			
1∼10			7		35	5						6	10	40	10			
11∼25				32	35						17	31	30	40				
26∼50		20	14	26	5	5					67	31	40	5				
51∼75			21	21	10							31	15					
75∼100			21	11	5						17		5					
> 100			36	11														
0						8	92								12	96		
1∼10		17			4	48	4								20			
11∼25				4	16	16							4	12	28			
26∼50		33	6	30	12	12							9	24	16	4		
51∼75		33	24	4	16	8	4					23	17	8	16			
76∼100			29	17	16	8						15	9	8	8			
> 100		17	41	43	36						100	62	61	48				
0								48								24	65	
1∼10							12	52					25		8	24	29	
11∼25				50		9	32					50	0		17	12	6	
26∼50						4	36					50	13		13	16		
51∼75						4	12						0		8	8		
76∼100						9	4						0	0	0	0		
> 100				50	100	74	4						63	100	54	16		
0																		
1∼10														17	5		36	
11∼25									32						10	4	20	
26∼50							5	17	40						19	12	16	
51∼75							0	13	24					17	10	16	20	
76∼100							0	4	4					0	5	0	0	
> 100						100	95	67						67	52	68	8	
0																		
1∼10								4										
11∼25								4	4									
26∼50							7	0	4									
51∼75							7	0	20									
76∼100							7	0	0									
> 100						100	80	92	72							100	100	100

Table 3. Variations in occurrences of the leaf blast and the stem rot of rice plant.

a. Norin 16

Date of investigation	N			2N		
	Average no. of tilers per hill	Leaf blast No. of lesions per hill	Stem rot No. of lesions per hill	Average no. of tillers per hill	Leaf blast No. of lesions per hill	Stem rot No. of lesions per hill
July 14	17.4	1.8	3.4	16.6	1.0	8.6
18	15.6	3.6	3.8	22.3	6.0	4.3
21	19.9	3.2	3.4	19.0	4.6	6.6
27	19.2	2.8	4.0	15.8	2.8	4.5
Aug. 2	18.0	1.0	5.0	19.6	0.4	9.4
9	16.6	0.8	4.2	17.6	0	8.0
18	17.0	—	—	16.2	—	—
31	18.6	—	—	17.6	—	—

b. Norin 21.

July 14	18.8	0.5	0.8	11.8	2.2	4.2
18	14.0	0.5	3.3	13.5	1.3	8.8
21	17.6	2.6	5.0	14.8	3.6	6.8
27	18.6	6.0	4.8	14.8	2.2	2.2
Aug. 2	14.3	1.3	1.3	13.4	1.0	2.6
9	15.0	0.3	4.3	16.8	0	8.6
18	15.0	—	—	13.2	—	—
31	15.2	—	—	18.6	—	—

c. Moko-ine

July 14	12.8	22.5	5.5	13.2	11.4	10.2
18	12.8	51.5	9.5	15.3	28.8	10.3
21	15.0	48.0	10.8	14.2	57.8	14.0
27	15.6	31.2	11.8	15.4	26.8	17.4
Aug. 2	15.2	17.2	17.2	14.0	12.8	17.4
9	16.8	0	8.6	12.0	5.8	15.6

lower leaves on the same haulm and increased with the lapse of time after the emergence of a leaf. Thus, it may generally be said that aged leaves bear more abundant lesions. On the influence of nitrogenous fertilizer, though not appreciable, it is conceived that the increase of lesions would tend to be slower in 2 N plots.

Illustration of these relations may lead to a clearer understanding. Fig. 2 shows the trends in the number of lesions due to the ageing of leaves in Norin 21 variety. Briefly speaking, the shift of curves to the left indicates the decrease of lesions and that to the right the increase. For instance, as for the fifth leaf, on July 14 no lesions appeared, whereas on July 27 the leaves with no lesion became 12 percent, those with 1–10 57 percent ,with 11–25 16 percent, and with 26–50 16 percent ; further, on August 9 the leaves with 0,1–10, 11–25, 26–50 and 51–75 became 25, 25, 25, 16 and 18 percent, respectively. As for the third leaf, there were indicated 0(84 percent) and 1–10 (16 percent) on July 27, 0(5 percent),

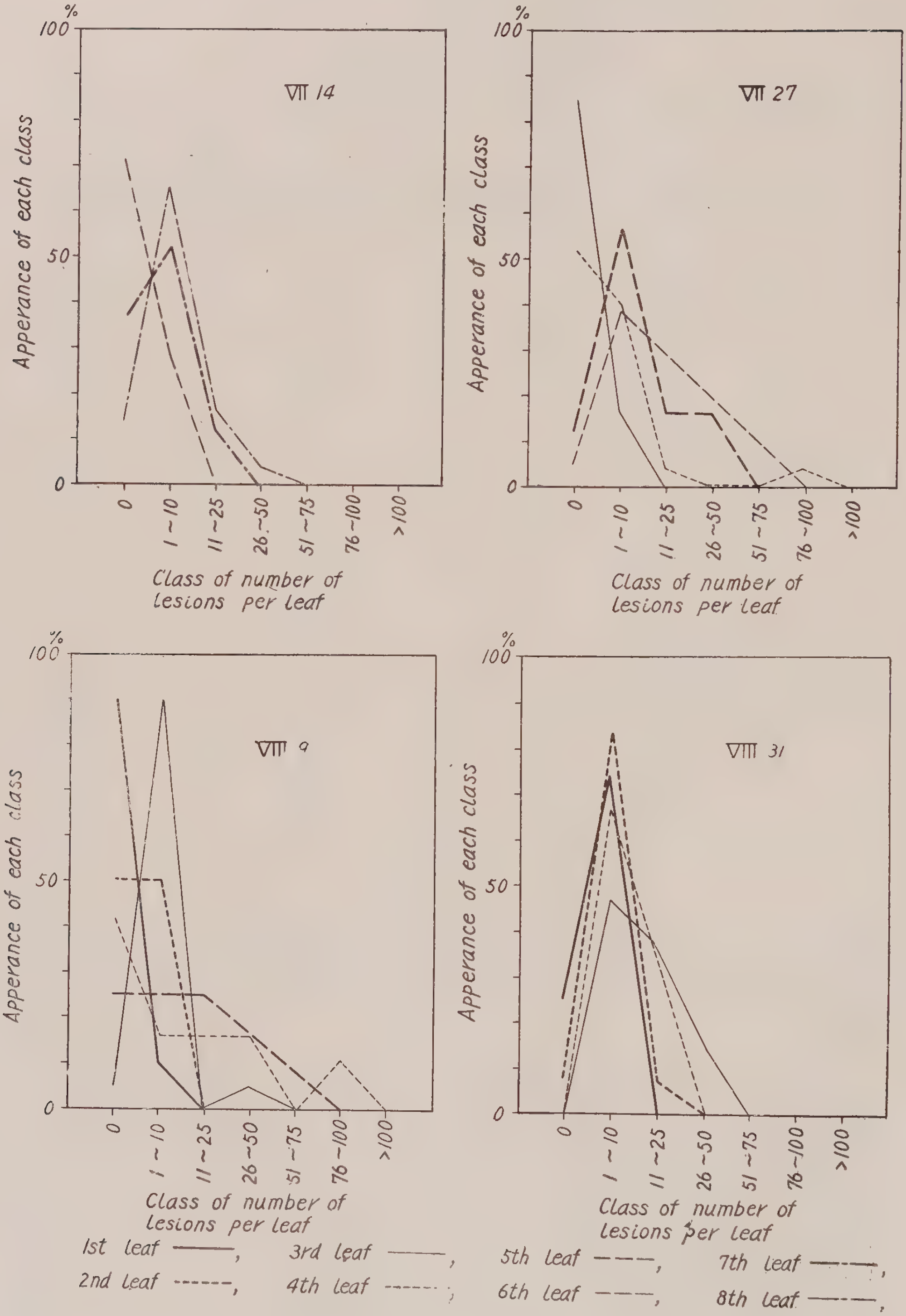

Fig. 2. Variations in the number of the blight lesions per leaf due to different growth stages. Explanation in text. (Norin 21 variety)

1–10 (47 percent) and 26–50 (5 percent) on August 9, and 0(0 percent), 1–10 (47 percent), 11–25 (37 percent) and 26–50 (16 percent) on August 31, thus showing an increase in successive date.

Fig. 3 illustrates the different infections on each leaf, examined on August 2, due to the respective position on the same haulm. For instance, in the case of Norin 16 variety the first leaf showed 0(100 percent), the third 0(48 percent) and 1–10(52 percent), and the fifth 0(55 percent), 11–25 (32 percent), 26–50 (5 percent), and 51-75 (5 percent). In the case of Moko-ine, the first leaf indicated 11–25(32 percent), 26–50 (40 percent), 51–75 (24 percent) and 75–100 (4 percent), while the third 26–50 (5 percent)and numbers more than 100 (95 percent).

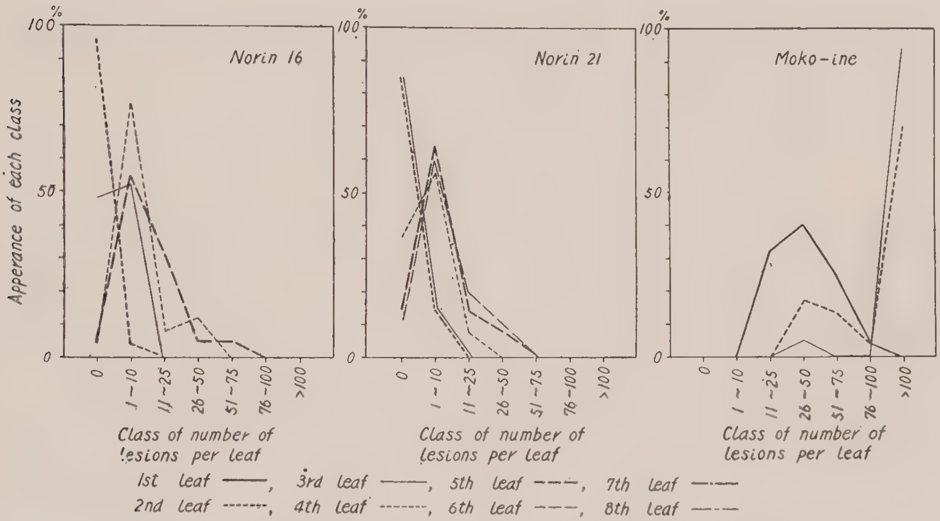

Fig. 3. Variations in the number of the blight lesions per leaf due to different leaf posions on August 2. Explanation in text.

Fig. 4 illustrates the differences of infection degrees among the varieties used in this work only with the third leaf. The increase of lesions after emergence of a leaf was extremely conspicuous in the case of Moko-ine, but it was not remarkable in the case of Norin 16 and 21, showing dubious difference between them.

Lesions observed throughout the investigation may be classified into the following 4 types from distinct pathological pictures of the infected tissues and their sizes :

Type A : small lesions without a venenate zone adjacent to the necrotic part or with light-brownish, narrow band around the necrotic part ; so-called "fine"[9] or "brown spot"[10] type ;

Type B : typical lesions of the leaf blight with a distinct necrotic and venenate zone, sometimes attain more than 3 mm in length ;

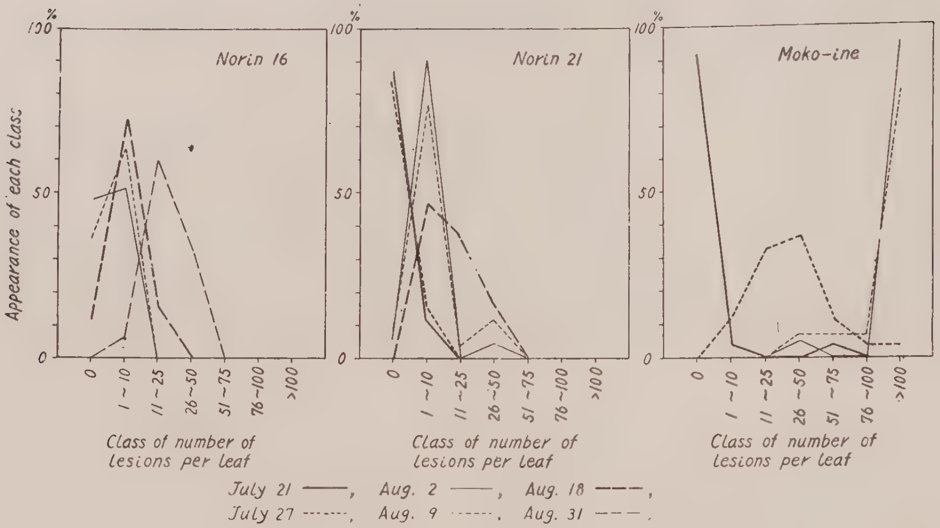

Fig. 4. Varietal differences in number of the blight lesions (the thrid leaf). Explanation in text.

Type C : lesions with a blackish-brown colored necrotic part and hardly recognizable venenate zone, sometimes become as large as type B ; so-called "black spot" type;[10)]

Type D : lesion is usually larger than any other type and sporulation is seen frequently ; so-called "gray spot" type.[9)10)]

It is likely that the type of lesion tends to shift from A to B with advancing stages of plant growth in view of the symptoms appearing on the leaves of Norin 16 and 21 throughout the entire period of investigation. Lesions of type D were recognized frequently on the lower leaves after the head-bearing stage and even on the flag leaves after heading.

Lesions appeared on leaves of Moko-ine plant are distinguished from the typical lesions of the leaf blight : the venenate zone can be hardly recognized and the boundary between the affected and healthy tissues is obscure. They do not belong to any type of lesion above mentioned. Such lesions were formed usually on the leaves of Moko-ine plants throughout the experimental period, and they often produced conidiospores in a moist chamber.

Trend in successive appearances of the above mentioned types of lesions suggests that the reactions of leaf-tissue against infecting pathogen may be changed by different growth periods of plants ; further studies on patho-histological changes of various lesions will answer the question.

Leaf blast and *stem rot* : As shown in Table 3, the occurrence of the leaf blast decreased rapidly after the end of July. Moko-ine, compared with the other two varieties, produced abundant lesions on the leaves. Influence of

nitrogenous fertilizer was not observed so distinctly. Rapid increase of lesions from the primordial stage to the head-bearing stage and their abrupt decrease after heading were similarly observed in all varieties. The type of lesions at the decreasing period was so-called "stagnant type".

The occurrence of the stem rot tended to increase with the advancing growth of plants, but was not so remarkable with the exception of Moko-ine.

III. Observations on Sheath-inoculation

Pathogens were inoculated artificially to the inner epidermal tissue of a sheath of rice plant. Observations on the invasion process of the pathogen into a host tissue, the subsequently induced pathological changes of the infected host tissue and the behavior of hyphae within host tissue by means of this inoculation procedure[11)12)] have been widely employed for the studies on the leaf blast disease. It is an effective method to examine the varietal resistance of rice plant to the blast or to study histologically and histochemically the patholgical changes induced by the pathogen in living host-tissues. Goto,[9)] and Yoshii and Matsumoto[14)] applied this technique to the investigation of the leaf blight disease.

To elucidate the applicability of this technique to the study of the leaf blight, the authors atemtpted a comparative investigation on the aforementioned fluctuation of infection degree by the blight fungus due to different growth periods on leaves of the rice plant grown in a paddy field and on that obtained by applying artificially the sheath-inoculation technique to the same plant material.

1. Materials and method for observation

Leaf-sheath: The sheaths to be tested were obtained from the same plants which are shown in Table 1. Before August 18, sheaths of the third leaves numbered from the uppermost ones on respective investigation dates and, after August 31, those of the second leaves numbered from the flag leaves were employed, but in the case of Moko-ine those of the second leaves were employed after August 2.

The leaf blight fungus: Suspension of conidiospores formed on Richards' agar emdium (25°–27°C, 10 days) was used as a inoculum. Inoculated sheaths were incubated at the temperature of 23°–24°C in a moist chamber placed in a dark room for about 30 hours, and then, after stripping off the infected inner epidermal layers from the inoculated sheaths, they were preserved in 20 percent alcohol solution before observations.

The leaf blast fungus: Conidiospores used in the inoculation test were obtained mainly from lesions on leaves of Moko-ine plants before July 27 and from those of Norin 16 after then. With the exception of the incubation period of 48 hours, the procedures were the same as those in the test of the blight fungus.

2. Results of the observations

The leaf blight: Based on the behaviors of the pathogen within the affected

host-cells, the degrees of invasion were calculated according to Takahashi's formula[12)]*, and their fluctuations in the course of plant growth are given in Fig. 5. Curves tracing the fluctuations of degrees of invasion during the growing period showed approximately the similar tendencies in all varieties tested. However, the peaks appeared earlier in Moko-ine (July 27) as compared with the cases of Norin 16 and 21 (August 9 and 18, respectively). It is interesting that the maximum rises in degree of invasion in all varieties are found at the period from head-bearing stage to heading. Effect of surplus nitrogen fertilizer (2 N plots) might retard the time of maximum rise in degree of invasion with Norin 16 and 21. Although the maximum degree of invasion was not remarkable in 2 N plot. Moko ine variety showed a slow descending curve.

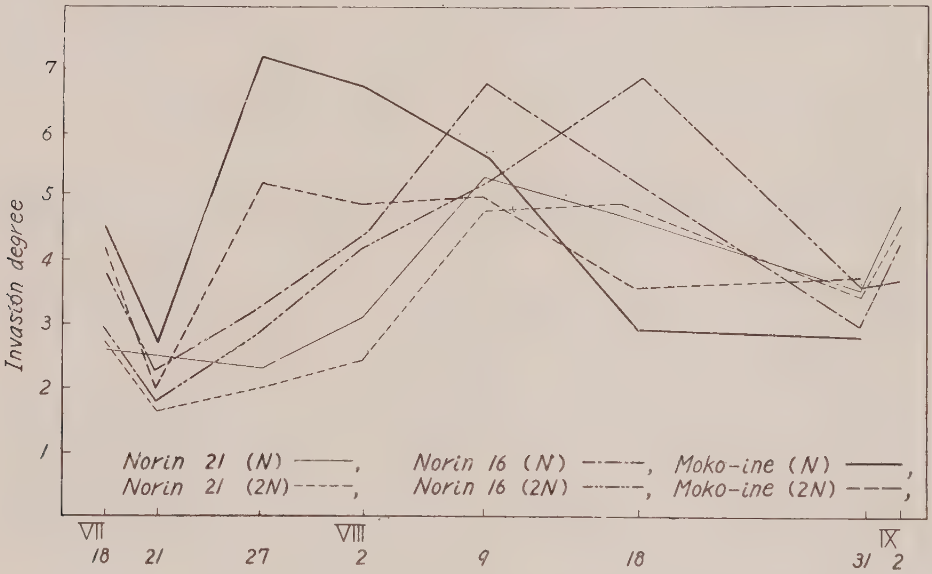

Fig. 5. Periodic changes of the invasion degrees determined by the sheath-inoculation method with the leaf blight fungus.

The leaf blast: Fluctuations in degree of invasion in the course of plant growth are given in Fig. 6. Curves showed steep slopes on both sides of the maximum peaks in all varieties. Their abrupt rises were observed on July 21–27 (Moko-ine) or on July 27–August 2 (Norin 16 and 21). These periods fell approximately on the head-bearing stage ; and after heading the curves dropped

* $v=\frac{\Sigma df}{n}$: where v indicates the degree of invasion or infection grade; d the class value, viz., 0. 5, 1, 2, 3, and 4, shown by each appressorium; f is an individual number which belongs to each class; and n the total number of appressoria except in the case of 0, viz., a case in which no invasion can be observed.

abruptly. In the case of Moko-ine, the effect of nitrogenous fertilizer was seen conspicuously.

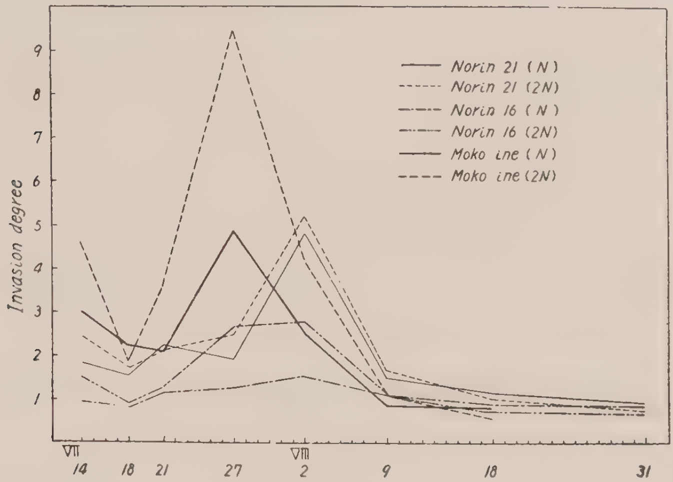

Fig. 6. Periodic changes of the invasion degrees determined by the sheath-inoculation method with the leaf blast fungus.

When comparing the fluctuation in degree of invasion obtained by the sheath-inoculation technique with the transition of natural infection described in the preceding section, the following conclusions may be drawn :

The leaf blight : Occurrence of the disease in Moko-ine variety in the paddy field increased remarkably from July 21 to 27 and further to August 2 (Fig. 4, third leaves). The maximum degree of invasion by the pathogen within infected host-cells was on July 27, indicating high value even on August 2. The head-bearing-heading stage seemed to be a turninng period for both trends. Neither Norin 16 nor Norin 21 showed intensive development of the disease, but slight increases of lesions were seen on August 2–9–18 (Fig. 4, third leaves). Thus, the changes in outbreak of the disease in both varieties were almost coincident with the respective trends of the invasion degrees as in the case of Moko-ine variety. However, the reason why the invasion degrees after this period showed descending trends with slight increases on September 2, despite the still intensive development of the disease in paddy field, is not clear.

The leaf blast : It should not be appropriate to compare directly the fluctuation in invasion degrees observed in a particular leaf with the trends in disease occurrence represented by the number of lesions appearing on a whole plant. However, it may show the relationship between them. Occurrence of the disease increased intensively from a period near head-bearing to heading stage and retarded after heading ; this may be coincident with the trend of invasion degree. How-

ever, the stagnancy of invasion-degree curve at the beginning stage of the plant growth was incomprehensible.

As already mentioned, the occurrence of the leaf blast increases toward the head-bearing stage or heading stage and retards after heading, while that of the leaf blight shows a reversal trend. Generally speaking, the shifts of the occurrences of respective diseases may be in conformity with those of invasion degrees determined by the sheath-inoculation technique. In other words, susceptibilities of rice plants to both diseases varied adversely before and after the heading stage. However, scrutinizing the results in detail, there can be found certain discrepancies as already pointed out. Whether these should be attributed to the insufficient representation of invasion degrees or to certain technical defects in this inoculation procedure, or whether these may suggest the limiting application of this technique to such investigation requires future studies.

IV. Floating in air of conidiospores of the pathogens in paddy field

Different aspects, if any, in conidial floating of both fungi may throw light on the different aspects in occurrence of the respective diseases in the paddy field.

1. Method of investigation

The paddy field under investigation is the muck paddy field mentioned in section II. Investigation was made from late June to early September; and, on August 1–2 and 10–11, the diurnal floating was examined every 3 hours. As shown in Table 4, spore-traps were placed at the heights of about 30 and 100 cm

Table 4. Location of spore-traps in paddy field

No. of trap	Plot	Height of trap (cm.)	Remarks
I	Norin 21 (N)	100	These were used to the investigation on outbreaks of the diseases
II	Norin 21 (2N)	30	
III	Moko-ine (2N)	30	
IV	Moko-ine (N)	100	
V	Norin 21	30	Occurrence of the leaf blight in these plots were similar to those in the above four.
VI	Norin 21	100	

above water level in the center of the experimental plot of the paddy field, on which three slide glasses coated with glycerine jelly[15] were arranged. Number of conidiospores found in the area of 18 mm² (a size of an ordinary cover slip) were counted under the microscope. To prevent slide glasses from rainfall, they were sheltered under a roof of 40 centimeter sqaure.

2. Results of investigation

Results of the investigation are given in Figs. 7 and 8. Conidiospores of the leaf blast fungus were observed already at the end of June, though the number was small, and floated most numerously at the end of July. They decreased rapidly after early August, and a few were obtained still in early September. Change in conidial floating may correspond with the fluctuation in occurrence of the disease. As compared with the blast fungus, conidial flaoting of the blight

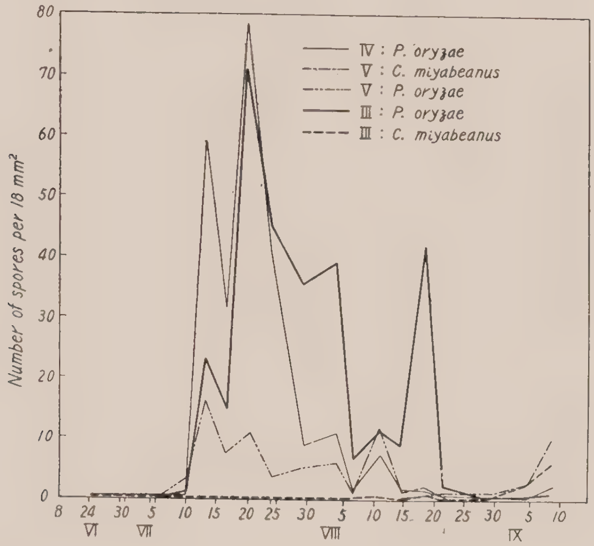

Fig. 7. Seasonal fiuctuations in number of conidiospores of the leaf blight and the leaf blast fungi arrested by spore-traps on muck paddy field.

fungus was extremely few, although they increased slightly in early September. Sudden retardation in conidial floating of the blast fungus in August may be attributed probably to the scanty sporulation due to the appearance of the "stangnant" type of lesion. On the other hand, sporulation of the blight fungus could not be found on the lesions of A type and, even in comparatively large lesions of B and C types, it was hardly observe as long as the leaf-tissue remained green. As already stated, large lesions of D type readily produced condiospores. Consequently, the slight increase at early September may be due probably to spore production both on the lesions of D type and on the large lesions of B and C types on withered leaves.

In the paddy field the blast spores were produced abundantly and traveled far, whereas the scantily produced blight spores might be incapable of long-distant flying ; Yokogi *et al.*[17] reported that they floated low. Thus, one of the reasons for different features in occurrence between both diseases may probably exist in their different abundancy in condia production and in their different ability of floating.

The results of investigation (August 1-2) on diurnal floating of the blast conidia are given in Fig. 8. No blight conidia could be obtained. Although the air was exceedingly dry through the long lasted fine weather, dew-fall was observed on leaves of the rice plants at about 6 p. m. with the drop of temperature.

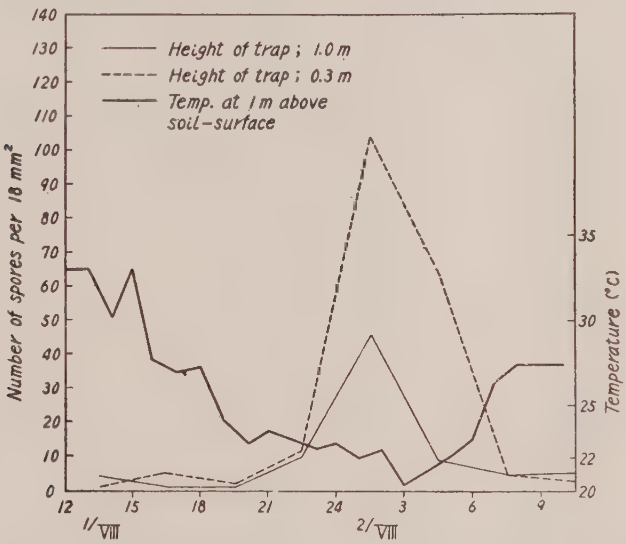

Fig. 8. Diurnal fluctuation of floating conidiospores of the leaf blast fungus

The atmosphere around the plants would thus be in saturated humid conditions at night. Conidial floating was meager in the daytime. It became abundant gradually from evening and rapidly attained the maximum after midnight. Then it was followed by a rapid decrease and reverted again to the daytime value. Results obtained on August 10–11 showed also a similar trend, but the maximum floating was not so remarkable as during August 1–2.

In every case the number of conidia obtained by the spore-trap near the ground was greater than that higher up.

V. Consideration

Before considering the foregoing results, it is necessary to outline the contributions to the knowledge concerning the "low productivity of muck paddy field" by other members of the research group in this Institute, and also to refer to the comparable results obtained in the high productive paddy field, belonging to blackish brown loam soil,[8] located at the foot of a hill about 1.5 km north of the muck paddy field. The former field exceeded the latter by more than 30 percent in yield every year. Occurrence of the diseases was found scarcely.

Comparing the growth of rice plants (Norin 21 variety) in both fields,[6)7)] at early stages of development the plant height in the latter exceeded that in the former. After July 20–27, however, its growth retarded suddenly. Number of tillers of plants grown in the latter field was less than that in the former, and its curve suspended after the maximum tillering. As a rule, the plants of the muck paddy field fell behind those of the high productive field in dry weight and root development. In view of nutrient absorption,[6)7)] the former was much inferior to the latter during its early development, and further, after the stage of internodal elongation, potassium was far less absorbed.

The results of observations on different occurrences of the leaf blight in soil-exchange experiments at the Shonai Experimental Farm of the Yamagata Agriculture Experiment Station[17)] indicated that severe outbreak was found exclusively in the soils, which showed its usual occurrence. Sakurai[19)] reported that different depths of peat deposits in paddy soil induced different occurrence of the disease. Consequently, there is no doubt that such unusual plant growth and nutrient absorption enforced by unfavorable soil conditions should be closely related to the particular occurrence of the leaf blight.

Kawai *et al.*[19)] also reported that severe outbreak of the disease occurred particularly in the year endowed with continuous high temperature and long insolation during the period from the end of July to the middle of August. As shown in Fig. 1, prevalent occurrence of the disease in 1955 was found to be related similarly with high temperature and long insolation during the same period.

However, it is not clear how both findings are related causally. In the rice plants under the usual pot plantation lesions can be produced almost throughout the entire period of growth by artificial inoculation. Yet none of the large lesions, which would degenerate the host tissues greatly and easily produce conidiospores as found in the muck paddy field, can be observed. Consequently, it is not conceivable that rapid development of the disease may be induced successively by the secondary infection originated from such lesions. Accordingly the appearance of large lesions capable of vigorous successive infection[20)] should be watched especially in view of the epidemiological standpoint.

As pointed out by Misawa,[21)] the influence of nitrogenous fertilizer has been viewed differently by many workers. In the present studies, rice plants in 2 N plots beared less lesions of both ordinary and large types than those in the control plots, but at later stages a reversal tendency was observed.

After all, it is important to find what factor or factors may effect the appearance of such large lesions capable of vigorous secondary infection in rice plants grown in a muck paddy field inducing usually a severe outbreak of the leaf blight. Thus attention should be paid to the pronounced role of such sporulating large lesions in the develompent of infection chain of the present disease.

The authors have previously considered the leaf blight and the leaf blast as

an endemic and an epidemic disease respectively. Such characteristics may be attributed probably to their differences in the development of infection chain, that is, in abundancy of sporulation on lesions and mode of dissemination, on the one hand, and also to the appearance of lesions of the former disease, capable of vigorous secondary infection, related closely to particular soil conditions on the other.

The results of investigation obtained in the muck paddy field indicated that the leaf blast occurred in earlier stages of plant growth, while the leaf blight in later stages, and their shifting periods fell just on the same period from head-bearing and to heading stage. The different occurrence of both diseases due to growth-stages of rice plants was also pointed out by Padmanabhan *et al.*[22] With regard to this contrasting phenomenon, it is necessary to clarify the reasons why the lesions of both diseases, capable of vigorous secondary infection, should be produced exclusively in different growth-stages of the same host plants. This may lead necessarily to the studies on the physiological and pathological specificities of both pathogens and on the specific defense reactions of host tissues against invading pathogens.

VI. Summary

The present investigation was made to clarify the fluctuation through the whole growth period in the outbreak of certain diseases (the leaf blight caused by *Cochliobolus*(*Helminthosporium*) *oryzae*, the leaf blast caused by *Piricularia oryzae*, and the stem rot by *Helminthosporium sigmoideum* var. *irregulare*) of rice plants grown in humus rich, muck paddy field in Miyagi Prefecture in 1955. Three varieties, viz., Norin 16 and 21, and Moko-ine were tested.

1. Number of the blight lesions increased with advancing stages of plant growth, especially after heading. Lower (older) leaves were more infected than upper (younger) leaves on the same haulm. Large and sporulating types of lesions appeared at the later stages of the growth. The blast lesions appeared abundantly at the earlier stages of the growth, and then decreased rapidly, especially after heading. The stem rot occurred most severely before heading.

The effect of nitrogenous fertilizer seemed to delay the increasing rate of number of the blight lesions. It caused a severe occurrence of the leaf blast and the stem rot, especially in the susceptible variety, Moko-ine.

2. Conidial numbers caught by a spore-trap were examined at certain intervals from late June to early September in the paddy field, The blast conidia were found most abundantly from mid-July to mid-August, and then decreased rapidly ; while the blight conidia obtained were only extremely few during the above period, except for a slight increase early in September. Diurnal fluctuation of floating conidia of the blast fungus was also examined on fine days (August 1–2 and 10–11). They were comparatively few at daytime and abundant at night

The maximum floating was found at midnight.

3. Variations in disease proneness to the leaf blight and the leaf blast throughout the whole period of plant growth were examined artificially by means of the sheath-inoculation on the same materials used in field observations on the disease occurrence. Evaluation of disease proneness was based on the degrees of invasion by the pathogens within infected host-cells.

The degree of invasion by the blast fungus was high in earlier stages of the plant growth and suddenly declined after heading ; while that of the blight fungus was rather high after heading. Thus the trends in the outbreak of both diseases in the field seemed to correspond, as a whole, to the respective fluctuations in the degrees of invasion by both pathogens.

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On the Relationship between Vegetation and Soil at Mountain Grassland in North-eastern Japan

Part 2 Studies on the soil in Onikôbe grassland.

Ichiro YAMANE, Iwao ITO, Ikuo SATO, and Kazuo SATO

(Recieved on March 22. 1957)

I. Introduction

The authors have been making an investigation on the relationship between soil and vegetation at mountain grassland in Kawatabi Experimental Farm attached to Tohoku University since 1954. As this grassland was used by the extinct Japanese Army in per-way days, it has been placed under different social conditions from ordinary grassland for the use of farmers. In general, the grasslands are located on a hill country covered with the soil of volcanic ashes and are being used as the grazing land or the cutting land. In order to compare with Kawatabi this grassland which is situated under the paticular social condition, the authors attempt to study the ordinary grassland which are used by farmers. The grassland in Onikôbe village adjacent to a mountain grassland in Kawatabi Experimental Farm was firstly studied. Of this grassland, the grassland areas under the management of Komukai and Tano blocks in this village was subject to the present work.

In the investigation on the mountain grassland in Kawatabi, the authors recognized a corresponding relationship between vegetation and soil, i.e., in places of high productivity of native plants the depth of humus layer is very thick and lime is accumulated on surface soil.[1)2)] Special consideration is given in the study of the grassland in Onikôbe village whether this relationship would be applicable to the grassland which is characterized with different topographical conditions and utilization forms and further how the erosion of soil would affect on the formation of thick humus layers. In the present investigation, no efforts are made for drawing diagrams of distribution or classification of soils.

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II. Enviromental conditions and history of the grassland

1. Location

Onikôbe village is located on the north-western corner of Miyagi prefecture, bordering Yamagata prefecture in the west, Akita prefecture in the north. The geographical location of the village is illustrated in Figure 1.

Fig. 1. Onikōbe village

2. Climate

The climate of Onikōbe being similar to that of Kawatabi, the average annual temperature is 11°C and the total of annual precipitation is 2137 mm. The climograph is shown in Figure 2. As this district is connected in the north-west with a saddle ridge of the Ohu range, Onikôbe is as snow-drift zone by the north wind during the winter season and becomes the place where the humid clouds hang low and the thunderstorm is frequently seen in summer. In particular, the precipitation during the period from the latter part of autumn to spring in the succeeding year is remarkabl and the village is confined by snow about one third of a year.

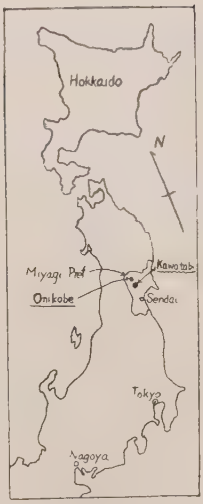

Fig 1. (2)

3. Geology[3)]

The basal conglomerate in this district is comprised of granodiorite and phyllitic clayslate, above which the tertiary period series is piled. In other words, a round ingression was taken place there by the crustal movement of the Ohu range, by which result tufaceous slate was accumulated in the lake formed in the ingression-basin. The volcanic activity was occurred in a part of the basin together with the accumulation of tufaceous slate. Firstly, the evolution of andesite was taken place there and was followed by the acid volcanic acitivity. As Mt. Arao underwent deudation and dissection, no geographical features at that time are remained. Being opposit to a mountainous land of granodiorite, the geological composition of the grassland is the fan deposit (alluvium) and is considered to be covered with volcanic ashes. In front of the grassland, there is a hill comprised of fragile slate, sandstone and conglomerate.

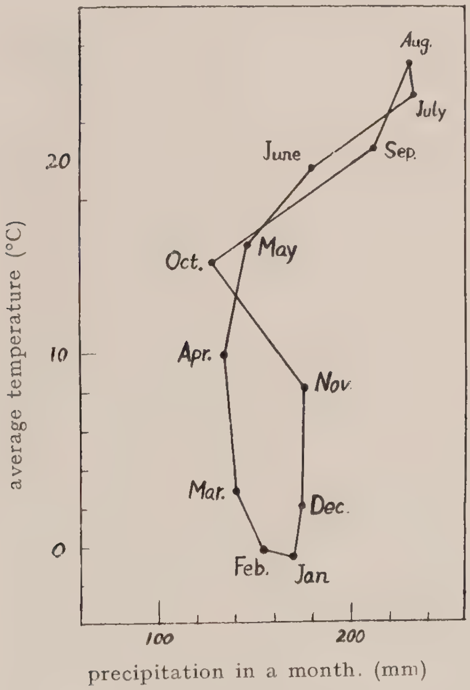

Fig. 2. Climograph

4. Geographical features

Being a basin surrounded by mountains 600–1,200 m above the sea-level, Onikôbe district presents an outlook of caldera. However, it has no entity of

such a type mountain, because the ambient mountains are non-volcanic and the mountain in the center is comprised mainly of aquenous rocks except the coverage of volcanic rocks only on the summit. The river Arao circulates around Mt. Arao and joins with the river Eai through the southern valley after merging 12 tributaries on the right bank and 7 on the left bank. The river flows on the lower land of the fragile base composed of conglomerate and slate, but it comes to erode the bed of the upper stream and form a flat land because of the blocking of its flow by a hard base around the southern valley. This tract has been utilized as paddy fields for many years, but there are seen frequently the accumulation of earth and sand by a number of floods in these years. A grassland of about 5000 acres deploys in a fan shape having the mountain lands behind it in the west and south, the inclination of which is 10–20 degrees and faces the river Arao across a low hill.

5. Vegetation

In view of plant climate, the tract is situated on the border between the warm temperate deciduous forest zone and the cold temperate deciduous forest zone. This grassland is surrounded by forests dominated by *Fagus sylvatica* and *Quercus aliena*. In grassland is observed *Quercus glandulifera* as the secondary forest.

There are observed about 40 plant species, of which *Miscanthus sinensis*, *Pteridium aquilinum*, *Zoysia japonica* and *Potentilla Freyniana* are dominant.

III. Outline of Utilization

The villagers depend their livelihood upon the proceeds from charcoal-making and income as daily laborers for the Forestry Office, most of the land being the national forest. Such being limited by the income sourse, their income in cash is extremely small. Besides, they rely the supply of food on the cultivation of paddy fields, but the yield of which is so scarce as to be sold. In spite of being famous for the production of horses by the utilization of land of about 5000 acres, the income of villagers is out of proportion to the long famed-name. Farm cattles have been mainly raised after the end of the war instead of horses. The average number of farm cattle per household is 1–2 heads, but the sale price of these cattle which are sold after 2 year-care at home is no more than 10,000 yen (about $ 28) to 15,000 yen (about $ 42), the amounts unable to draw any good profit. As mentioned above, the yield of rice crop is extremely small due to the cool irrigation water. Such scarcity of income and the yield of rice unsufficient even for self-sustenance had the authors wonderous whether they can maintain livelihood in this village, although the existence of poor farming villages is not rare in Japan. In general, it is characteristic that a vast grassland in the north-eastern districts of Japan is attached to such a mountainous village and is distributed in a belt form in the arrangement of the paddy field district, upland farm

district, houses, privatly owned forests, grassland and national forests (see photo 1). The privately owned forests were afforested with *Cryptomeria japonica* and *Fagus sylvatica* within 100 years ago and cutting is available once a period for 30–40 years.

The grassland is located outside the privately owned forest and situated at a distance of about 3–4 km from the housing area generally. The grassland divided by difference of utilization and ways of utilization are also regulated by each community. The grassland subject to the present study is classified in four types as follows.

1. Grazing land : The land in which grazing of horses and cattles is taken place for a cerain period under surveilance of 1 or 2 watchmen. In this village proprietors bring cattle and horse to the watchman in the morning for grazing and he gathers them at a place for the delivery to the proprietors in the evening. Grazing of cattle in the grassland after July 20 is impossible by the outbreak of the horsefly, because cattles are driven to gather onto the housing area. This district is enclosed with earth fences, each enclosure being 50–100 acres.

2. Cutting land

This is the land to cut the native grass, which is divided into the following three area according to the cutting method.

(i) Cutting land I. (Place of cutting in summer)

This land is subject to cutting in the morning and evening from spring to autumn. The farmers rely the forage for cattle during summer on the native plant collected at that time. Cutting is limited in a way of allowing full of a shoulder basketser household two times a day in the morning and evening. In case of loading on an ox-cart, the collection of native plant is allowed every two day. This work is carried out 2 or 3 hours before breakfast, and is one of heavy labors for the farmers. Although the native plants are used for feeding cattle, they are mixed frequently with bracken type plants unpalatable for cattle, by which farmyard manure is made. This manure is applied to paddy fields. Therefore, native plants of this type plays an important role as material for formyard manure rather than forage for cattle. Poverty of the village forces the farmers to use such manure abundantly (5∼6 tons per acre) with the difficulty in purchasing chemical fertilizer. The farmyard manure has never been applied to the grassland.

The native plants in this grassland, although better than those in the grazing land, were exceedingly bad in quality.

(ii) Cutting land II. (Hay cutting place)

This is the place in which a full force of the village comes to cut plants towards September. As the plants are still greenish at the time, farmers bring them back after dried them for two or three days. They are stored as crude forage in winter.

The quality of plants is better than in cutting land I.

(iii) Cutting land III (*Miscanthus* cutting place)

This is the place where cutting is taken place at the beginning of November immediately before the snowfall, and *Miscanthus sinensis* is grown vigorously. The land aims are to cut *Miscanthus sinensis*. Farmers in such a village thatch the roof with *Miscanthus sinensis*, so that the plant is inconsiderable part being used for this purpose. In order to keep the house warm, they protect their houses from blowing snow by enclosing with a snow protection made of weaven *Miscanthus*. *Miscanthus* is also used for making charcoal bags.

Although this grassland is not connected directly with livestock raising and agriculture, it is being treated most carefully in such a mountainous village in this paper. As a forage for cattle, there was observed *Lespedeza bicolor*. Being the most essential forage in winter, cutting of *Lespedeza bicolor* is restricted in the seuerest way. The plants distributed in the land together with other species and is cut simulatneously with them by a full force of the village. Although the yield can not be estimated accurately, *Lespedeza bicolor* is not grown so dominant there that hay grasses (dried native plants) supplement the shortage of it as the forage in winter.

Presently the cultivation of pastural plants (grasses and legumes) is not undertaken, and grazing of dairy cattle is rarely seen.

3. Method of observation

The present investigation was made in the middle of August. As both of Tano and Komukai grasslands in the village expand geographically in a fan shape, the boring investigation is made on a straight line in each enclosure at a distance of 100–150 m from the top height of the grasslands to downwards. On this ocassion, the investigation is made of the degree of cover and plant height by species of plant. Four enclosures respectively in Tano and Komukai are subject to this study, besides which one place along the contour line is surveyed in respective cases.

After the above-mentioned preliminary investigation, the detailed investigation of the forest of *Cryptomeria japonica*, cutting land III (*Micanthus* cutting place), cutting land II (hay cutting place), cutting land I (cutting place in summer) and grazing land is made by digging pits. The growth weight of plants is sought, sampling soils for analysis, investigating vegetation of plants and cutting the acreage of 4 squere meters. The soil of each horizon is sampled. The accumulation of lime abundant particularly in the depth of 3 cm of the surface soil in Kawatabi[2] forces to sample the soil 0–3 cm below the ground. The method of soil analysis is accorded with the common method.

4. General characters of soil

The soil of the two districts is the soil of volcanic ashes. The A horizon of

black or dark blackish brown color, the B horizon of dark brown or blackish brown color and the C horizon of yellowish brown color are observed in soil profile in condiserable part.

When viewed the mineral composition (Table 1), the soil is mainly composed of glass component (regardless of colorless or brown ones) and of plagioclase as the secondary constituents, while hypersthene and magnetite are little and none of quartz is observed. All cases are considered to be the soil belonged to andesite. The mother material of this soil resembles to that in Kawatabi, but is not the same in a strict sense.

Table 1. Mineral composition

		glass	plagioclase	hypersthene	magnetite
Tano	A-horizon	90	9	0	1
	C-horizon	90	9	0	1
Komukai	A-horizon	83	15	2	0.5
	C-horizon	75	22	1	2

Table 2. Analysis of hot HCl extract

		Fe_2O_3	Al_2O_3	P_2O_5	HCl-SiO_2	Na_2CO_3-SiO_2	SiO_2 sum	SiO_2/Al_2O_3
Tano	A-horizon	3.19	6.04	0.12	0.11	8.49	8.60	2.41
	C-horizon	4.87	7.75	0.11	0.11	7.10	7.21	1.58
Komukai	A-horizon	3.43	7.30	0.12	0.14	11.53	11.67	2.61
	C-horizon	6.30	13.08	0.11	0.13	13.10	13.23	1.71

Tabel 3. Mechanical analysis

		coase sand 2– 0.2	fine sand 0.2– 0.02	silt 0.02 –0.002	clay < 0.002	
Tano	A-horizon	11.8	22.0	48.5	17.7	silty clay loam
	C-horizon	14.1	20.5	31.0	34.4	light clay
Komukai	A-horizon	11.2	27.6	43.7	17.6	clay loam
	C-horizon	1.5	55.4	40.0	3.1	loam

Table 4.

	P_2O_5 absorption coeff.	available P_2O_5	available K_2O
Tano A-horizon	1860	0.0038%	0.023%
Komukai A-horizon	2150	0.0052	0.021

The ratio of silica/alumina in hot HCl extract (Table 2) is high (2.5) in case of the humus layers (A horizon), but is less than 2.0 in each case of the subsoil (C horizon). The soils are high in the coefficient of phosphate absorption and the percentage of available phosphate (soluble with 0.2 N HCl) is exceedingly

small showing the soils in severe lack of phosphorus. The percentage of humus is more than 20% and the volume percentage of solid phase is about 20%, while the percentage of water is extermely high. The soils are acid strongly and the texture tend to incline to clayly rather than to the loam soil (cf. Table 3, Supplementrary Table 2)

As stated already, these soils may be characterized that they present much blackish in the topsoil and are the soil of volcanic ashes in strong acidity, abundant in humus and lacking phosphorus. As no cultivation has ever undertaken, it is assumed that these soils should be greater in humus and N percentage than those of volcanic ashes ordinarily termed.

A forest of *Quercus glandulifera* is situated behind the grassland on a steep slope whose base is very fragile. Therefore, there have been frequent landslides owing to heavy rains, which resulted in the supply of gravels and stones into the land. With the promulgation of a law concerning the protection of grasslands thirty years ago, these obstacles were cleared out but there are still seen gravels and stones scattering on the surface soil and in some plot gravels even inside the soil. This finding was utterly different from the grassland in Kawatabi where none of gravels more than 2 mm in size are observed.

5. Relationship between vegetation and depth of humus layer

A close relationship between vegetation or grass weight and depth of humus layer (A-horizon) was observed in the mountain grassland in Kawatabi Farm. The results of examination as to whether such relationship would be occurred in this grassland will be mentioned in the following, by selecting three enclosures in Tano and Komukai blocks respectively under different conditions.

These grassland are divided into grazing land and cutting land which are further subdivided into cutting land I (place of cutting in summer), cutting land II (hay cutting place) and cutting land III (*Miscanthus* cutting place).

Although the utilization areas are regularly decided, what need more consideration is that grazing and cutting of grasses are not always followed to the same arrangement. For instance, in case of grazing, cattle tended not to gather at the upper part so as to cause the dominace of *Miscanthus sinensis* in vegetation.* Besides, in case of the cutting land I, such an upper part of land is subject to less frequent cutting by the handicap of distance and thereby takes the form of cutting land III sometimes (For example, encolsure A).

According to the illustration in Figure 3 and Supplementary Table 1, this may be explained as follows.

Enclosure A (Tano): Being about 1,000 m of a slope in length ,the area

*Although this may not be the case in a grazing land with a slope of short distance, dominant vegetation was observed in the upper land in Komukai grassland with a long and steep slope.

is for the most part the cutting land I, but the upper parts of which are frequently utilized as the cutting land II (hay cutting place) or cutting land III (*Miscanthus* cutting plase) substantially as the result of a small number of frequrency of cutting. Therefore, in the foremost upper region *Miscanthus sinensis* is found dominantly and decreased in number more and more downwards against the increase of *Pteridium aquilinum*. The better is in growth of *Miscanthus sinensis* the thicker become the depth of humus layer. In spite of a slope of 10 degrees in the average gradient, the erosion of soils is not recognized.

Enclosure B (Tano) : Being a slope of about 1,200 m, the upper the direct-ion is the steeper become the slope. Divided into the national forest, cutting land III, cutting land I, grazing land and *Cryptomeria japonica* forest from the upper region downwards, the utilizing conditions (division of utilization) can be readily recognized by a glimpse. In the cutting land III, the degree of cover of *Miscanthus sinensis* is 4–5 and the plant height is high, while *Lespedeza bicolor* is comparatively dominant, but *Pteridium aquilinum* (bracken) was not so substantial. In spite of a small number, *Pteridium aquilinum* is distingui-shed in plant height. Although *Pteridium aquilinum* exceeds in lieu of the disappearance of most of *Miscanthus sinensis* plant height of the former become low.

In the *Zoysia japonica* is the dominant species among which *Pteridium aquilinum* is interspersed. Although *Pteridium aquilinum* is comparatively numerous in the grazing land of this grassland, the spot is abundant in *Zoysia japonica* because of facing to the road. Although spots 6 and 7 are situated in the upper region of the cutting land I, *Miscanthus sinensis* is more prominent in number and plant height than that in the lower region under a smaller influence of cutting.

The thickness of humus layer seems not to be affected by the difference of geographical distribution, but it is likely that it should be thicker with the increase of vegetation. Despite of the dominance of vegetation, the humus soil are not so thick in spots 1 and 2 as expected. This may be attributed to the displacement of soils (or the withered plant bodies) on account of such a steep slope at 32 degrees in gradient. The reason for the formation of thick humus layers in spot 10 may be due to the fact that the spot is apt to be subject to humidity and sedimentation of soils as the result of its location just beyond the earth fence.

Enclosure C : Although the area is on a slope of 1,200–1,300 m, it is being utilized as the cutting land III, cutting land II and graziing land from the upper region downards. In the cutting land III *Miscanthus sinensis* is dominant in good conditions of growth, being similar to the case of enclosure B. However, *Petosites japonicus* becomes dominant and the humus layer forms quite deep in spot 5, as the spot is located in a concave ground under high humidity. The dominance of *Pteridium aquilinum* followed by *Miscanthus sinensis* is observed

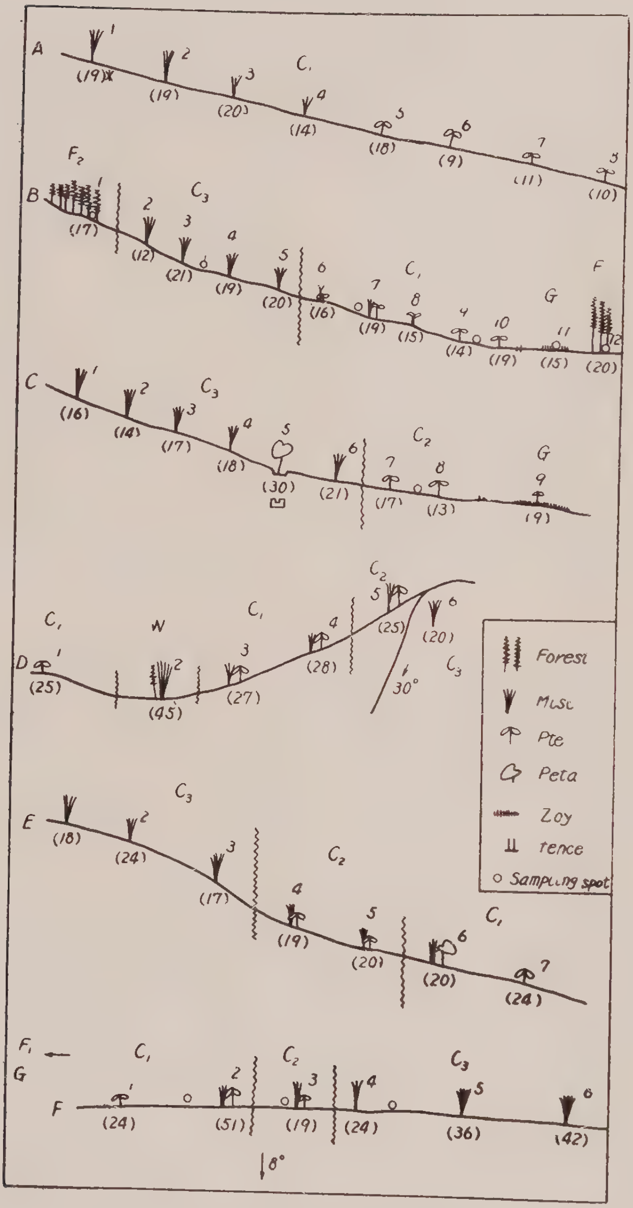

Fig. 3. Utilization from, vegetation and humus layer
(*thickness of humus layer)

G : grazing land, C_1 : cutting land I, C_2 : cutting land II,
C_3 : cutting land III, F_1 : private owned forest F_2 : national forest
W : swamp 凹 : concaved spot Misc. : *Miscanthus sinensis*
Pte. : *Ptelidium aquilinum*, Peta. : *Petasites japonicus* Zoy. : *Zoysia japonica*

in the cutting land II, showing a little difference from the aforesaid cutting land I (This may be attributable to an inconsiderable influence of cutting as the result of the substantial approach to the cutting land in its location on the lower land). *Pteridium aquilinum* and *Zoysia japonica* are dominant in the grazing land, while the plant height of *Pteridium aquilinum* becomes much smaller.

With the exception of spot 5 which is located on the concave ground, it is observed that the humus layers become thicker in the upper region with the increase of vegetation.

Enclosure D (Komukai) : The area is a steep slope of about 300 m ranging from spot 1 to spot 5. The swamp in spot 2 was abundant in reed (*Phragmites communis*), there are also seen *Castanea pubinervis* and *Quercus glandulifers* about 3 m in height. In the cutting land I (spots 1, 3 and 4) *Pteridium aquilinum* is dominant and *Miscanthus sinensis* is observed scatteringly, and the cover degree and plant height of the latter are small. Being dominant species, *Micanthus sinensis* and *Pteridium aquilinum* are high in plant height in the cutting land II. In spot 6 on a steep slope at 30 degrees by the side of spot 5, the humus layer is somewhat thinner by the gradient of about 30 degrees, but in which *Miscanthus sinensis* is dominant and its plant height is considerably high. As seen from the growth of plants partial to humidity such as *Cocalia hustats*, *Senescio palmatus* and *Petasites japonicus*, the spot is in high humidity. It is interesting that high humidity is observed in such a spot on the upper land forming a steep slope owing to the utilization of the land in the form of the cutting land III.

Enclosure E (Komukai) : Being located on a slope of about 1,000 m in the north, the area is divided into the cutting land III, cutting land II and cutting land I from the upper land downwards. The inclination is generally steep showing a gradient of 25 degrees in spot 3. The cutting land III is dominated by *Miscanthus sinensis*. As seen from the growth of plants partial to humidity such as *Senecio palmathus*, it is likely that high humidity brought about the remarkable development of *Miscanthus sinensis* in spot 6. The thickness of humus layers show little difference. It is noteworthy that the humus layers are considerably thick in spots 2 and 3 in spite of the inclination of slope at 20 degrees or more.

Enclosure F (Komukai) : Taking the skirts of the fan-shape land along the contour line, the area inclines at about 8 degrees. The cutting land III has *Miscanthus sinensis* as the dominant species and the cutting land II had the same dominant species with a considerable number of *Pteridium aquilinum*, while the cutting land I consisted mainly of *Pteridium aquilinum* among which *Miscanthus sinensis* is interspersed. Although the humus layer is not seemingly so deep in the cutting land III, there are observed deep humus layers like spot 2. The present division of utilization in this enclosure has been materialized for past 10 years. Before this new division, all areas of the enclosure is utilized

as the cutting land III.

The fresh weight (standing crop) measured by cutting the acreage of 4 squers meters together with the investigation of vegetation on the sampling spots for analysis, is illiustrated in Table 5. From this figure, the differentiation of yields of plant owing to the form of utilization may be elucidated.

6. Relationship between vegetation and soil in view of the results of chemical analysis

The samples for analysis are selected from enclosures B and F. Standing on the understanding that enclosure F contains grasslands of multiple types on the reach to show a new conventional utilization and an unsubstantial relationship between vegetation and humus soil layers, the enclosure is chosen in the constrasting sense to enclosure B. The outline of the spots is tabulated in Table 5 and Supplementary Table 3. The sampling spots are recorded on the Figure

Table 5. Fresh weight (Standing crop)

		fresh weight kg/m²	vegetation *Miscanthus*	*Pteridium*	*Zoysia*	thickness of humus layer
Tano	1) cutting land III	2.0	5 (140)*	+ (100)	—	23 cm
	2) intermediate	0.9	2 (75)	2 (60)	—	11
	3) cutting land I	0.6	1 (45)	4 (40)	+ (10)	13
	4) grazing land	0.4	+ (25)	3 (45)	2 (10)	15
	5) cutting land II	0.75	1 (70)	4 (55)	—	17
Komukai	1) cutting land III	2.8	5 (155)	+ (100)	—	36
	2) cutting land II	1.4	4 (110)	1 (80)	—	15
	3) cutting land I	0.75	1 (55)	4 (50)	—	19
	4) grazing land	0.6	—	5 (35)	+ (10)	12

* Degree of cover (cm in height)

3 of enclosures B and F. The litter layer is observed in the forest zone, but it is not detected in the grassland. Although the difference of the surface soil of 0–2 or 3 cm from the lower strata is appreciated in the case of boring, there is recognized no discrimination in the case of digging of pits. Different appreciation may be presented in case of boring because of the abundance of roots in the surface soil.

The analytical results are shown in Supplementary Table 2, Table 6 and Figures 4 and 5.

i) Humidity of soils

Although all forest zones show high humidity and other grasslands in Tano presented higher humidity with the prominence of vegetation, such a trend is not observed in the case of Komukai grassland. For instance, low humidity in the cutting land III of Komukai may be attributed to the low percentage of humus. However, in case of the boring experiment, it is appreciated that the greater vegetation is the more would become humid. Humidity in field is considered

to be regulated by aridity of the surface of earth and the percentage of humus in soils. The percentages in volume of solid, liquid and air phases in the soil volume are tabulated in Table 6, sampling of the surface soil (0–7 cm) into

Table 6. Volume per cent in soil (Enclosure F)

	solid phase	liquid phase	air phase
forest	16.0	66.0	18.0
cutting land III	23.0	48.3	28.1
cutting land II	22.6	52.0	25.6
cutting land I	24.9	46.3	29.2
graging land	20.4	51.2	28.4

a sylinder of 100 cc. This experiment is undertaken in spots of Komukai enclosure F, the results of which show no relationship between humidity (water percentage) and vegetation. It is worthy paying attention that the percentage taken by solid at the value of 20 % is extremely small, though this tendency is similar to the mountainous grassland in Kawatabi.

ii) Carbon, humus, nitrogen and carbon-nitrogen ratio (C/N)

Applying the Tyurin's simplified titration method for the analysis of carbon, the percentage of humus is obtained by multiplying the resultant values of carbon by 1.723. The measurement of nitrogen is made by the decomposition method with HgO.

As shown in Figure 4, the percentages of carbon and humus are high in all the soils and become higher particularly in the surface soil, being more than 40–60% (20–30% of carbon) in case of humus percentage of the humus layer in forest zones. In the case of Tano, these percentages are extremely high in the cutting land III (40% of humus). There is observed no difference in percentage in other lands despite of the difference of the thickness of humus layers. The low percentage in the case of Komukai may be attributed to the mixture of sands into the soil. In the asympotitic stratum (B-horizon) and subsoil (C-hori zon) the percentage is generally settled, presenting the percentage of humus at 10–5%. Although the percentage

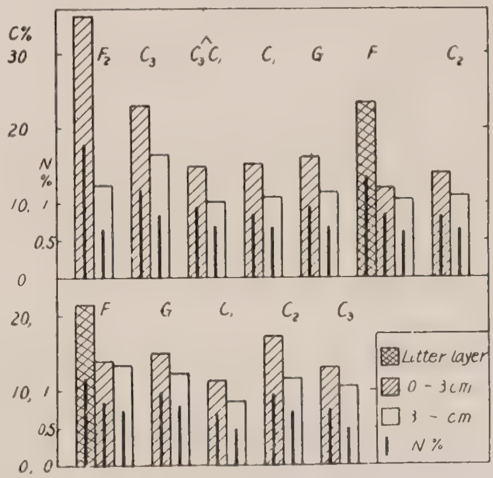

Fig. 4 carbon and nitrogen

C_3C_1 : intermediate of C_1 and C_3

of carbon and nitrogen in the subsoil of yellowish brown color may not be said to small, it is of interest that the percentage in this case is extremely greater than the subsoil in other types of soil.

Although the percentage of nitrogen is parallel to that of carbon, the decrease of carbon-nitrogen ratio become smaller with the approach to the deeper layer, showing that the percent of nitrogen become smaller in deeper layer than that of carbon. In the surface soil of 0–3 cm all soils show the nitrogen percent in the approximity of 1%.

iii) Exchangeable lime and pH

The exchangeable lime is measured by making the quantitative analysis of CaO in the extract for exchangeable acidity and pH is obtained in the water and the N-KCl suspension by the glass-electrode method (Fig. 3, Supplementary Table 2).

The exchangeable lime is abundant in the surface soil of 0–3 cm, being 3–10 times the following part of humus layer. Besides, the accumulation of lime in the forest and cutting land III which is by far greater than that in the cutting land I, II and grazing land, is similar to the result of investigation of the mountainous grassland in Kawatabi. It is noteworthy that the percentage of lime is high in the surface soil of cutting land III in Komukai despite of the scarcity of humus and nitrogen. In either of B-horizon and C-horizon showed the percentage to be 0.2% or less than 0.1%.

pH in case of the water suspension is at about 5 and pH in case of the KCl suspension is at 3–4, indicating the soil of strong acidity. In the same profile of soils, the humus layer downward from 3 cm is the lowest in pH and the value tend to become higher with the approach to the C-horizon. The surface layer shows high pH, but the rise of pH is extremely insignificant not exceeding 0.3, as compared with the increase of percentage of lime by 3-fold to 10-fold. This may be attributed to the abundance of humus.

iv) Titration acidity

The exchangeable acidity (Daikuhara acidity) and hydrolytic acidity are expressed in the titration value y_1 by extracting with N-KCl and N-Ca-Acetate respectively according to the conventional method (Fig. 5, Supplementary Table 2).

The exchangeable acidity is at 10–30 in case of the humus layers, and is comparatively small with the value less than 10 in case of the B-horizon and C-horizon. Hydrolytic acidity is so high as to show more than 70 and become lower remarkably to be 20–50 in approaching to the B-and C-horizon.

As shown in Figure 6, a corresponding relatiohnship between the exchangeable acidity and the percentage of exchangeable lime is observed in the humus layers, but relation of the former to the percentage of carbon is scarcely appreciated. On the contrary, in the case of hydrolytic acidity, it is not related to the exchan-

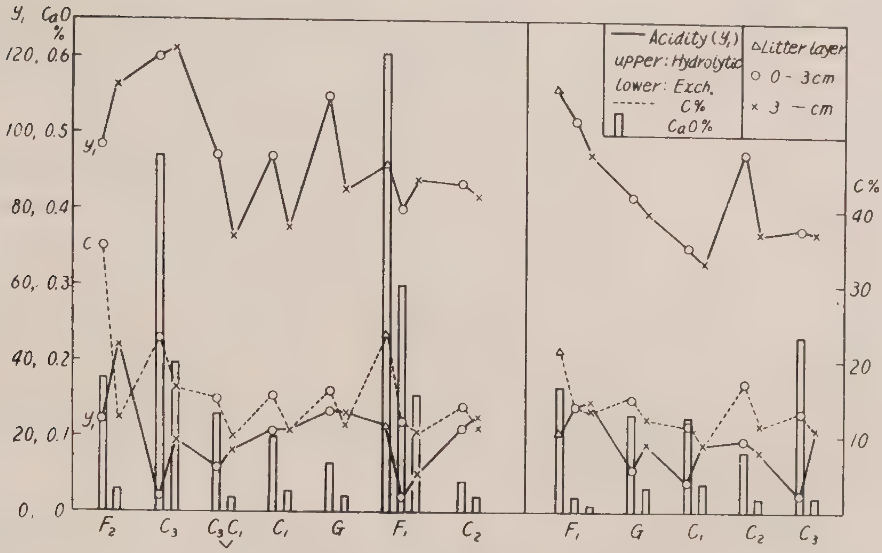

Fig. 5. lime content, acidity and carbon content

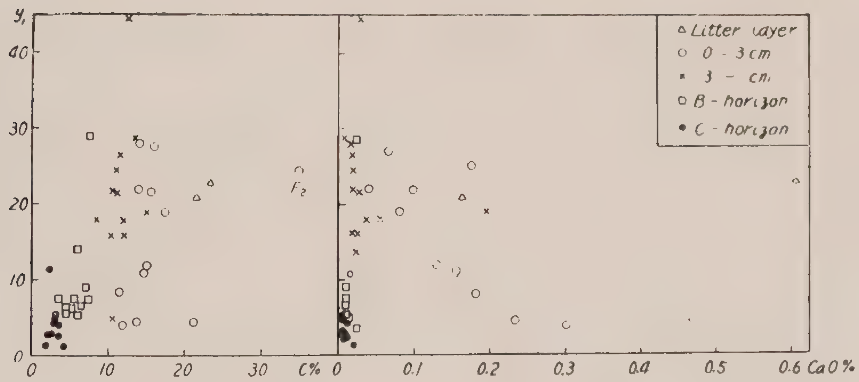

Fig. 6. Relation between exch. acidity and carbon or exch. lime.

geable lime, showing the corresponding relationship to the percentage of carbon.

7. Relationship among utilization forms, vegetation and soil

There is observed a close relationship between utilization forms (differred from utilization areas) and vegetation. *Miscanthus sinensis* is dominant in the cutting land III, showing the prominence of plant height. In the cutting land II *Miscanthus sinensis* become smaller numerically and *Pteridium aquilinum* become greater, both of which are smaller in plant height than the case of the cutting land III. In the cutting land I, *Pteridium aquilinum* appears as the

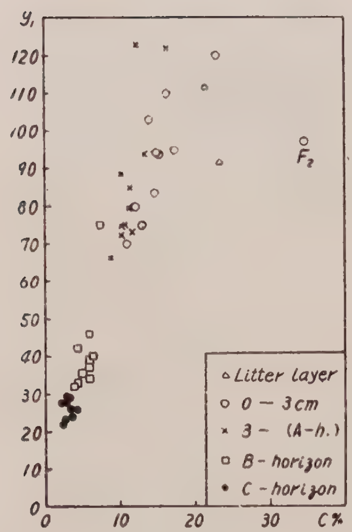

Fig. 7. relation between hydrolic acidity and carbon

dominant species and *Miscanthus sinensis* become scarce, while the plant height of the latter become also smaller than the aforesaid two cases. *Pteridium aquilinum* and *Zoysia japonica* become dominant in the grazing land.

Although a close relationship between vegetation and soil, particularly the thickness of humus layers (A-horizon) is observed, there are places in which no difference is taken place in the thickness of humus layers despite of the difference of vegetation. The variation of vegetation would occur rather quickly in correspondence with the variation of utilization forms of land, while such a variation as the formation of humus layer would take many years. Enclosure F may be the case to be considered in this way. In spite of a long duration of vegetation, there are cases not correspondent to the humus layer (enclosures D and E).

However, this grassland, as it is located on a slope of 10-15 degrees in gradient, should present the high humidity in lower part. Though the erosion doesn't occur, by this humidity the thickness of humus layer in lower part must become larger than that in upper part. On the contrary, investigation shows that there is little difference in the thickness of humus layers between the upper region and the lower region. The presence of thick humus layers in the upper region where a good development of growth of *Miscanthus sinensis* should be generally seen indicates that the difference of supply of the organic matter from plant into soil would affects the thickness of the humus layers. In view of the indication of high humidity in proportion to the development of vegetation, this fact may help the accumulation of humus.

In the places with a good development of vegetation, a remarkable accumulation of lime in the range of 3 cm in the surface soil is demonstrated. The accumulation of humus and nitrogen is abundant in such places, but the accumulation ratio of lime exceed by far over the both cases. The accumulation of lime is from 3–fold to 10-fold of the following stratum, while that of humus and nitrogen is from 1.5–fold to 2-fold. This may indicate that the accumulation of lime would be supplied by the stems and leafs, and that of humus and nitrogen should be construed as the supply from the stems, leafs and roots. In case of enclosure F in Komukai, the percentage of humus and nitrogen is not so great even in the cutting land III owing to the new division of utilization areas, while the accumulation of lime is remarkable. This may be considered to indicate that

the accumulation of lime would take place more speedy than that of humus and nitrogen. According to the survey in Kawatabi, such a difference of the percentage of lime should be revealed within 10 years[2].

However, being different from the case of Kawatabi, the difference of the plant weight measured in this paper does not express accurately the reducing amount into soils, as all plants are cutted at different stages. In cutting land III where the cutting is performed in latest, the leaves already wither and fall down. Considerable amounts (lime and oganic matter) of plants are reduced into soil. This amounts are far greater than that in cutting land I and II.

Although the characters of soil regulates influentially the growth of plants, the aforesaid facts may indicate that the effect of vegetation upon soil is greater than that of soil upon vegetation. The variation of soil in correspondence to vegetation demonstrates that the soil varies correspondingly to the difference of utilization forms, viz., there should exist a corresponding relationship among utilization forms, vegetation and soil. In this work, the influence of artificial undertakings is seen to alter a part of characters of soil. Therefore, the authors wish to lay emphasis that not only the natural conditions but also the human participations give the great influence on the formation and alteration of soils.

8. Soil erosion

The river Arao is well known for the occurrence of natural disasters such as frequent floods and ingression of cultivation lands by the displacement of earth and sands. Differently from the mountainous grassland in Kawatabi, this grassland has a large congregated water terrain behind it. From these respects, it is generally considered, including the authors, that the soil erosion of this grassland should be substantial. At the same time, it may be held true that stones and gravels in the forest zone behind the grassland would be carried away into the land together with trees by storms and simultaneously the carriage of soils would be taken place. However, according to the result of investigation, the accumulation of soils by erosion is not observed in most of the areas, and even if there were some cases, they would be considered to be limited to a certain locality.

The soils of earth and sands accumulated by floods in the Onikôbe Basin are composed of fragile tuff, having no direct relationship with this grassland. Consideration need not be paid so seriously to the erosion of soils in this grassland where grasses are grown. However, in the case of conversion of this grassland into the upland farm, particularly of cultivated crops, there is the possibility to cause a severe erosion of soils.

9. Improvement of soils

The soils of the grassland are allitic and phosphorus deficient soils in strong acidity being derived from volcanic ashes. Productivity of the present grassland

is 2~4 tons per arce, showing a fairly low productivity. (Productivty in the cutting land III is so high as 7 tons per acre, but the land is being utilized for an entirely different purpose). Presently the introduction of dairy cattle is not prevalent and the grazing of Japanese cattle is take place widely. As the annual income from grazing of Japanese cattle is more or less 10,000 yen (≒28 $) per household, the collection of grasses and grazing of Japanese cattle are continued by farmers to acquire farmyardmanure as well as the utilization of their labour. *Miscanthus sinensis* was rarely found and *Pteridium aquilinum* was abundant in the cutting land I. Therefore, most of them would be used for making manure instead of the use for forage. As the grasses are displaced from the grassland to be put into paddy fields as farmyard manure and not return again to the grassland, vegetation of the grassland will be deteriorated gradually. The plantation of *Cryptomeria japonica* and *Fugas sylvatica* narrow further the space for the growth of plants. In other words, this may be said to indicate the low productivity of the present graslsand.

In this work, the great effect of vegetation on the formation and variation of soils is elucidated. This may indicate the possibility to change soils by utilization of plants. As plants for this purpose, we can think of pastural plants (grasses and legumes). Pastural plants are more suitable to grow in the grassland under such cold climate as in this case rather than *Miscanthus sinensis* and *Pteridium aquilinum* which are dominant species in the land. The grassland in Mogami town, Yamagata prefecture, located opposite to this grassland, has been succeeded in the formation of an excellent pasture (about 50 acres) and increasing the acreage, although the grassland is similar in characters of the soil to the grassland in Onikobe. In view of the process of cultivation experiment on the newly settled Tano grassland, it is likely that the introduction of pastural plants could be carried out readily without the application of farmyard manure. The volcanic ash soils of this type are extremely abundant in percentage of N. However, as reported by Kurosaki et al (4), native grasses are great in dependence on soil nutrients and small in response to fertilizer, while pastural plants are greater in the response to fertilizer than the soil nutrients. *Miscanthus sinensis* shows a weak regeneration after cutting, while pastural plants seem to be acitve in regeneration. The conversion of the grassland to pasture may be materialized without difficulty, making use of the responce to fertilizer, regeneration capacity after cutting and adaptability to cold climate.

The success of pasture establishment constitutes the base for the development of dairy agriculture, and at the same time it is known experientially that the introduction of farm crops can be materialized easily in the sites of excellent herbs. Differing from the previous literatures which demonstrated the direct improvement methods of the grassland with the application of compost, phosphorus fertilizer and lime, the authors pointed out the possibility of soil improvement through pasture.

Moreover, in recent years the improvement of volcanic ash soils by irrigation has been drawn attention[5]. On the other hand, the success for the formation of excellent pasture by irrigation has been reported[6]. Presently paddy fields in this district are irrigated from samps and spring water, and these water resourses may be utilized in winter to create the irrigated pasture.

Summary

The authors have been making the investigation on the relationship between soil and vegetation in Kawatabi Experimental Farm. In this paper, an attempt was made to a certain whether the same relationship occured in the adjoining grassland in Onikôbe village.

As a result of the investigation, there was observed the existence of a consistent relationship among utilization forms, vegetation and soil in the grassland. Being a volcanic ash soil, this soil was the humus-rich soil in strong acidity in addition to which it is allitic, extremely high in the phosphate absorbing coefficient and deficient in lime and phosphorus. Such chracter of the soil regulates the growth of plants as well as agriculture as a whole, while the utilization form effects reversively upon plants and extensively on the chracters of soils.

Improvement of this (range) grassland has been considered to be very difficult economically. But the authors found that the plants convert the soil more fertile and so considered the pastural plants (grasses and legumes) as the plants most suitable for this purpose.

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Supplementary table 1. Utilization form, vegetation and thickness of humus layer.

Enclosure A

Spots	1	2	3	4	5	6	7	8
utilization	cutting land 1							
inclination	10	8	8	10	10	10	10	10
vegetation								
Mis.	4(120)	4(75)	3(45)	2(50)	1(50)	+(55)	+(49)	+(50)
Pte.	2(80)	1(60)	3(45)	2(50)	3(35)	3(40)	4(45)	3(45)
	Wei. 1(55)		Aru. 2(40)		Aru. 1(45)	Aru. 1(40)	Sal. 1(40)	Wei. 1(40)
thickness of humus layer	19	19	20	14	18	9	11	10

Enclosure B

spots	1	2	3	4	5	6	7	8	9	10	11	12
utilization	native forest	cutting land III				cutting land I					grazing land	forest*
inclination	32	20	13	8	10	7	7	7	7	7	3	3
vegetation												
Mis.	—	4(160)	5(120)	5(140)	4(100)	1(70)	1(70)	+(60)	+(55)	+(40)	+(35)	—
Pte.	—	2(120)	1(100)	1(90)	3(70)	2(60)	4(55)	5(65)	5(35)	5(35)	2(30)	—
		Wei. 2(80)	Les. 4(100)	Les. 3(100)	Les. 3(110)	Aru. 2(60)	Aru. 1(45)	Zoy. 3(10)	Aru. 1(35)	Aru. 1(30)	Zoy. 5(5)	—
thickness of humus layer	17	12	21	19	20	16	19	15	14	19	15	20

* *Cryptomeria japoncia*

Encolosure C

spots	1	2	3	4	5	6	7	8	9
utilization	cutting land III						cutting land II		grazing land
inclination	12	12	10	10	8	7	7	5	5
vegetation									
Mis.	5(150)	5(110)	5(110)	1(100)	1(170)	4(100)	1(80)	+(55)	—
Pte.	+(100)	+(95)	1(100)	5(110)	+(100)	1(90)	4(60)	5(60)	4(40)
	Pet. +(45)	Aru. 1(90)	Aru. 1(100)	Les. 1(100)	Pet. 4(45)	Les. +(90)	Aru. 1(60)	Les. +(45)	Zoy. 3(5)
thickness of humus layer	16	14	17	18	30	21	17	13	9

Enclosure D

spots	1	2	3	4	5	6
utilizatin	cutting land I	swampy land	cutting land I		cutting land II	cutting land III
inclination	5	flat	10	14	18	30
vegetation Mis. Pte.	1 (40) 4 (45)	1 (170) —	1 (55) 4 (55)	1 (65) 4 (60)	2 (110) 2 (100)	3 (170) 1 (130)
	Sal. + (60)	Phr. 4 (170)	Les. + (30)	Les. + (45)	Les. + (100)	Pet. + (100)
thickness of humus layer	25	45	27	28	25	20

Enclosure E

spots	1	2	3	4	5	6	7
utilization	cutting land III			cutting land II		cutting land I	
inclination	15	18	25	13	12	7	8
vegetation Mis. Pte.	4 (110) + (100)	5 (85) + (55)	5 (110) + (95)	2 (70) 3 (65)	2 (65) 3 (55)	4 (30) + (55)	1 (55) 4 (45)
	Les. 1 (100)	Les. + (70)	Les. + (110)	Les. + (65)	Les. + (60)	Cac. + (100)	Zoy. 1 (10)
thickness of humus layer	18	24	17	19	20	20	24

Enclosure F

spots	1	2	3	4	5	6
utilization	cutting land I		cutting land II	cutting land III		
inclination	8	10	10	10	10	7
vegetation Mis. Pte.	1 (55) 4 (55)	2 (55) 2 (55)	4 (125) 2 (75)	5 (140) + (100)	5 (155) + (110)	5 (150) + (100)
	Zoy. 1 (10)	Aru. 1 (50)	Les. + (60)	Les. + (60)	Les. + (90)	Art. + (85)
thickness of humus layer	24	51	19	24	36	42

Mis. : *Miscanthus sinensis*
Wei. : *Weigela hortensis*
Aru. : *Arundinella hirta*
Les. : *Lespedeza bicolor*
Art. : *Artemisia vulgaris*
Phr. : *Phragmites communis*
Pte. : *Pteridium aquilinum*
Sal. : *Salix vulpina*
Zoy. : *Zoysia japonica*
Pet. : *Petasites japonica*
Cac. : *Cacalis hastata*

	soil number	(cm)	water content %	C %	humus (C ×1.72)
Enclosure B					
national forest	48	1- 3	71.0	34.9	62.2
	49	3-17	44.0	12.3	21.9
	50	17-30	43.0	7.70	13.6
cutting land III	7	0- 3	59.5	23.1	39.8
	8	3-23	57.0	16.5	28.4
	9	23-36	49.5	5.96	10.3
	10	36—	42.5	3.61	6.20
cutting land II (?)	11	0- 3	44.0	15.0	25.9
	12	3-11	49.0	10.2	17.4
	13	11-17	47.0	6.50	11.5
	14	17—	42.0	4.24	7.31
cutting land I	15	0- 3	47.0	15.3	26.3
	16	3-13	49.0	10.9	18.0
	17	18-23	42.0	5.62	9.85
	18	23-26	49.5	9.53	16.4
	19	31—	37.5	2.68	4.63
grazing land	20	0-3	50.5	16.2	27.9
	21	3-15	43.0	11.7	20.1
	22	15-27	52.5	6.05	10.4
	23	27—	32.5	3.35	5.87
forest (*Cryptomeria japonica*)	1	0-1	60.5	23.5	40.5
	2	1-4	49.5	11.9	20.5
	3	4-13	47.0	10.5	18.3
	4	20-24	44.0	4.62	7.98
	5	24-29	49.0	3.05	5.25
	6	29	31.0	2.03	3.49
cutting land II (C)	24	0-3	46.0	14.1	24.2
	25	3-17	47.0	11.0	18.9
	26	17-24	51.0	7.10	12.3
	27	24	44.0	3.12	5.37
Enclosure F					
forest (*Cryptomeria japonica*)	32	0-2	59.0	21.5	37.1
	33	2-5	59.0	13.8	24.0
	34	5-11	57.0	13.5	22.9
	35	18-37	36.0	3.63	6.25
grazing land	28	0-3	48.0	14.8	25.4
	29	3-12	51.0	12.2	21.1
	30	12-23	49.0	4.82	8.31
	31	23-80	46.0	2.81	4.83
cutting land I	36	0-3	38.0	11.3	19.6
	37	3-19	41.5	8.76	15.8
	38	19-25	37.0	3.63	6.46
	39	25-75	42.0	2.46	4.39
cutting and II	44	0-3	49.0	17.2	30.6
	45	3-15	55.5	11.6	20.8
	46	15-19	48.0	6.01	10.3
	47	19	43.0		—
cutting land III	40	0-3	43.0	13.2	23.6
	41	3-36	44.0	10.6	18.9
	42	36-48	45.0	4.66	8.29
	43	48-90	44.0	2.44	4.35

N %	C/N	exchangeable lime CaO %	pH (H$_2$O)	pH (KCl)	exchangeable acidity y_1	hydrolytic acidity y_1
1.78	19.6	0.177	4.20	3.22	24.6	97.0
0.63	19.5	0.029	4.20	3.37	44.5	122.5
0.43	17.9	0.022	4.50	3.50	28.3	74.5
1.17	19.7	0.470	5.20	3.94	4.61	120.2
0.86	19.2	0.196	5.02	3.60	19.2	121.8
0.37	15.8	0.026	5.58	3.90	13.8	46.0
0.12	11.6	0.011	5.60	4.16	4.25	26.1
0.93	16.2	0.130	4.95	3.80	11.8	94.2
0.68	14.9	0.018	4.80	4.00	16.2	72.3
0.51	12.6	0.008	5.10	4.26	6.42	40.0
0.39	10.9	0.007	5.33	4.40	2.29	25.9
0.85	17.9	0.099	4.72	3.70	21.7	93.9
0.67	15.7	0.027	4.98	3.81	21.4	75.0
0.44	12.8	0.012	5.20	4.10	7.48	37.4
0.62	15.6	0.019	4.90	3.88	22.0	66.8
0.25	10.8	0.007	5.20	4.40	2.92	22.8
0.95	17.1	0.065	4.60	3.65	27.1	110.1
0.67	17.3	0.022	4.67	3.79	26.4	85.0
0.48	12.7	0.008	5.10	4.22	5.27	34.1
0.24	14.1	0.007	5.13	4.40	2.62	24.0
1.34	17.5	0.605	5.20	4.15	23.2	92.2
0.84	14.2	0.300	4.96	3.88	4.17	79.6
0.62	17.0	0.155	5.20	3.80	10.1	88.2
0.42	11.0	0.043	5.42	4.00	6.62	42.4
0.30	10.1	0.024	5.80	4.20	3.48	28.0
0.17	12.3	0.020	5.85	4.35	1.42	20.9
0.82	17.0	0.041	4.60	3.60	22.1	86.5
0.64	17.1	0.019	4.70	3.70	24.6	83.4
0.50	14.3	0.010	5.00	4.00	9.27	43.0
0.26	12.0	0.008	5.15	4.12	5.11	24.1
1.09	19.7	0.164	4.60	3.40	21.2	112.2
0.84	16.3	0.018	4.37	3.45	28.0	103.5
0.73	18.2	0.007	4.30	3.50	28.7	94.5
0.26	13.9	0.003	5.00	4.08	5.6	29.7
0.97	23.4	0.129	5.01	3.90	11.0	83.4
0.79	19.7	0.033	4.92	3.75	18.0	79.2
0.38	8.0	0.013	5.08	4.02	7.42	35.8
0.25	4.5	0.008	5.20	4.20	4.61	29.8
0.67	17.0	0.177	5.14	3.70	8.18	70.2
0.51	17.2	0.037	5.00	3.60	18.00	66.4
0.33	11.0	0.009	5.20	3.92	7.51	32.4
0.25	9.9	0.006	5.20	4.30	2.88	22.1
0.96	18.0	0.080	4.40	3.70	18.9	95.0
0.72	16.2	0.018	4.80	3.81	15.9	73.8
0.44	13.8	0.009	5.00	4.20	4.91	39.0
—	—	—	—	—	—	—
0.76	17.6	0.233	5.27	3.85	4.62	75.0
0.48	22.2	0.020	4.95	3.70	22.07	74.2
0.37	12.5	0.011	4.97	4.10	5.6	32.2
0.28	8.8	0.013	5.03	3.92	11.6	27.7

Supplementary table 3. Vegetation and soil profile for analytical sample.

utilization form	sample number	layer (cm)	color	texture	
Enclosure B					
national forest	48 49 50	0-1 1-3 3-17 17-30 30-35 35—	b ackish brown 〃 dark blackish brown greyish blackish brown dark brown yellowish brown	litter CL CL CL CL gravelly	inclination 32°
cutting land III	7.8 9 10	0-23 23-36 36—	black dark brown yellow brown	CL CL CL	inclination 14° *Miscanthus sinensis* 5140cm) *Pteridium aquilinum* + (100cm) standing crop 2.0kg/m²
cutting land II(?)	11. 12 13 14	0-11 11-17 17—	black dark brown yellowish brown	CL CL CL	inclination 10° *Miscanthus sinensis* 2(75cm) *Pteridium aquilinum* 2(60cm) Standing crop 0.9/m²
cutting land I	15, 16 17 18 19	0-13 13-18 18-23 23-26 26-31 31—	dark blackish brown greyish blackish brown dark brown greyish blackish brown dark brown yellowish brown	L CL CL CL CL CL	inclination 8° *Miscanthus sinensis* 1(45cm) *Pteridinum aquilinum* 4(40cm) Standing crop 0.6kg/m²
grazing land	20. 21 22 23	0-15 15-27 27—	dark blackish brown dark brown yellowish brown	CL CL CL	inclination 30° *Miscanthus sinensis* + (25cm) *Pteridium aquilnium* 3(45cm) *Zoysia japonica* 2(10cm) Standing crop 0.4kg/m²
forest (*Cryptomeria japonica*)	1 2.3 4 5 6	0-1 1-13 13-20 20-24 24-29 29—	blackish brown black dark blackish brown grey blackish brown dark brown yellowish brown	litter L L CL CL CL	inclination 5° forest of 30 years
cutting land II (C)	24.25 26 27	0-17 17-24 24—	black dark brown yellowish brown	CL CL CL	inclination 5-7° *Mitscanthus sinensis* 1(70cm) *Pteridium aquilinum* 4(55cm) Standing crop 0.75 kg/m²
Enclosure F					
forest (*Cryptomeria japonica*)	32 33.34 35	0-2 2-11 11-18 18-37 37—	blackish brown dark blackish brown dark greyish brown greyish brown gravel	litter CL CL CL	inclination 8° forest of 20 years
grazing land	28.29 30 31	0-12 12-23 23—	black dark brown yellowish brown	L CL CL	inclination 4° *Pteridium aquilinum* 5(35cm) Standing crop 0.6kg/m²
cuttihg land I	36.3 7 38 39	0-19 19-25 25-75 75—	dark blackish brown dark brown yellowish brown gravel	CL CL CL	inclination 8° *Miscanthus sinensis* 1(55cm) *Pteridium aquilinum* 4(50cm) *Weigela vulpina* 1(55cm) Standing crop 0.75 kg/m²
cutting land II	44.45 46 47	0-15 15-19 19-43 43—	dark blackish brown dark brown yellowish brown gravel	CL CL CL	inclination 8° *Miscanthus sinensis* 4(110cm) *Pteridium aquilinum* 1(80cm) Stiandng crop 1.4kg/m²
cutting land III	40.41 42 43	0-36 36-48 48-90	black dark brown yellowish brown	L CL CL	inclination 8° *Miscanthus sinensis* 5(155cm) *Pteridium aquilinum* + (100cm) mixed by sand Standing crop 2.8kg/m²

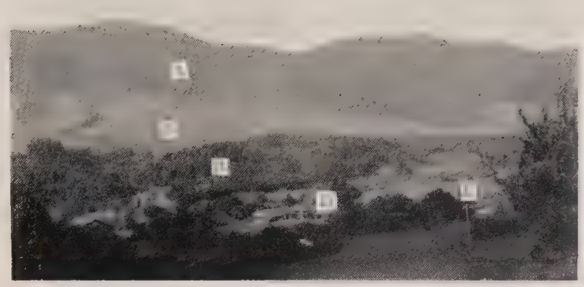

Photo. 1. General View

A national forest
B grassland
C private owned forest
D house of farmer
E paddy field

Photo. 2.

Private owned forest
and paddy field

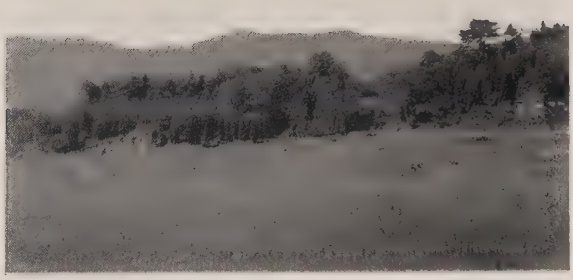

Photo. 3.

Grazing land

Photo. 4. Cutting land I
(Place of cutting in summer)

Photo. 5. Cutting land II
(Hay cutting place)

Photo. 6. Cutting land III
(Miscanthus cutting place)

Studies on the Grassland in Makassar Peninsula of Selebes Island

Shigeharu YOSHIDA

(Recieved on March 25. 1957)

I. Introduction

The author made the investigation on the natural grassland in the Makassar Peninsula of Selebes Island from June to July in 1944. Although the investigation was carried out in a limited extent owing to the influence of World War II then nearly ending and resulted in a brief and simple investigation, the author recompleted the materials in this paper in consideration of the significance of the investigation for reference to the studies on the *Bokuya* (natural grassland) in Japan or on the grassland in the areas abundant in rainfalls.

The opportunity for this investigation in the island was given by Late Dr. Ichiro Sonobe and Dr. Yōichi Kakizaki. The judgement for part of plants was made by Dr. Jisaburo Ohwi. The author wishes to express his hearty appreciation for their valuable assistance and cooperation in the subject investigation.

II. Outline of Agriculture

1. Climatic conditions

The Makassar Peninsula is situated in the proximity of lat. 5 S., but the atomospheric temperature is about 27°C ranging 20°C at the minimum to 30°C at the maximum. The variation of temperatures during a day is only about 7°C, although it is somewhat remarkable in the arid season.

In view of the monsoon, the rainfall can be divided roughly into the rainy season (from November to March) and the arid season (April to October). The distribution of rainfalls is given in Table 1. Although the rainfall is seen most frequently in a particular period generally, such an inclination is differerd according to the difference of topographical features and there are sometimes observed places in which no conspicuous difference in rainfall between the rainy season and the arid season is appreciated. Cultivation begins in general at the end of the arid

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Table 1. Rain-fall distribution in Selebes Island.

	1	2	3	4	5	6	7	8	9	10	11	12	total
Makassar	584	428	423	217	80	49	23	10	8	29	143	499	2493
Bonthain	114	115	123	142	206	205	123	47	25	19	77	111	1307
Watampone	151	161	214	310	345	358	213	103	74	113	145	159	2346
Pare-Pare	315	248	223	211	167	87	65	38	51	115	227	365	2111
Makale	226	231	331	389	237	153	114	71	78	116	194	223	2363
Kendari	194	130	208	189	203	198	119	60	28	19	74	173	1645
Poso	281	157	267	314	299	224	171	163	153	70	147	162	2408
Menado	617	252	296	244	156	153	138	140	66	111	180	267	2620

season and ends at the begining of the arid season.

2. Conditions of the land-utilization

The conditions of the land-utilization are illustrated in Table 2. In the investigated areas in the island including Makassar, Bonthain, Bone and Pare-

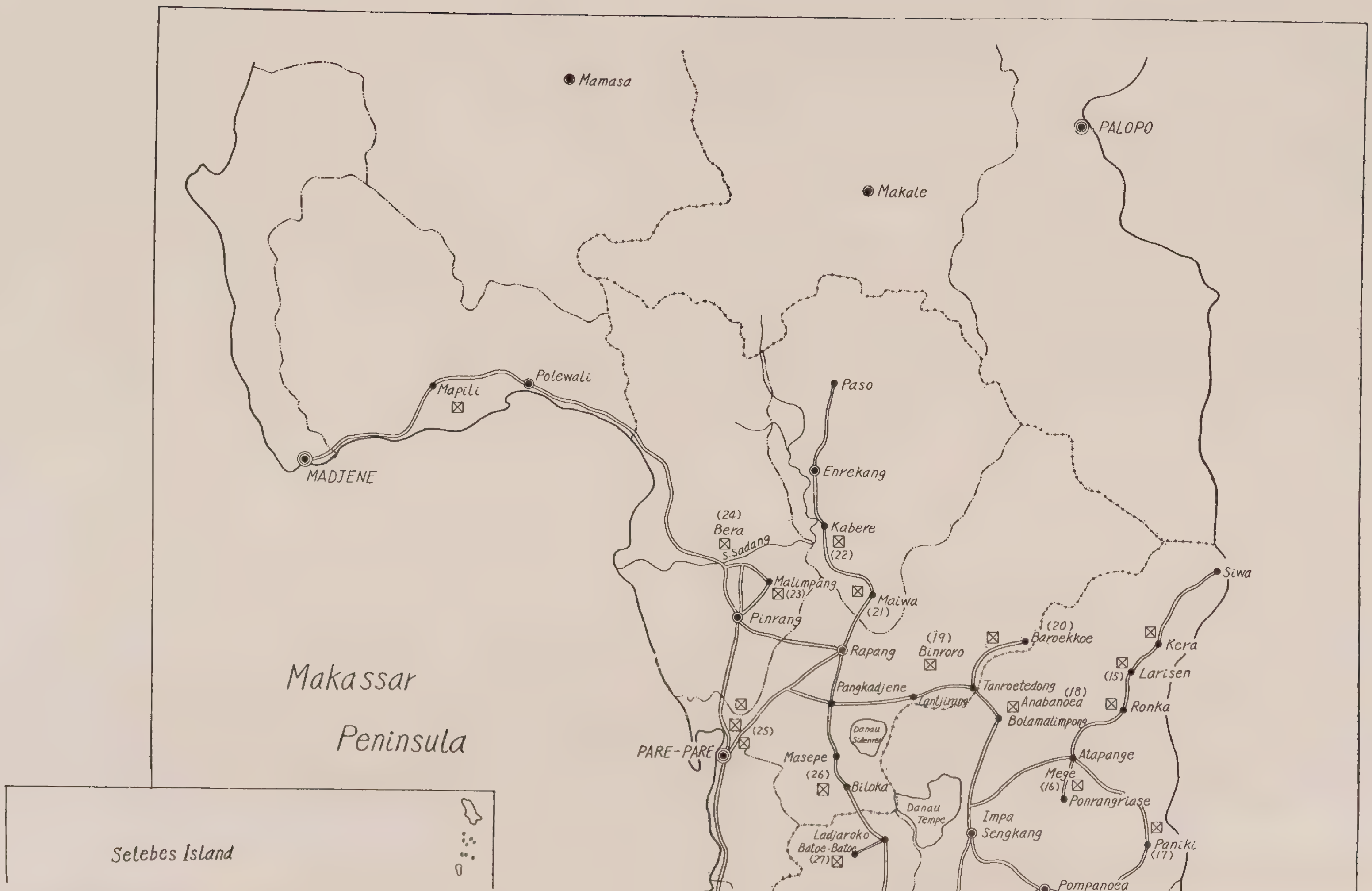
Table 2. Condition of land-utilization. 1942.

	Total area	Forest	Natural grassland	Rice field	Farm	Others	Number of famer house
Makassar	hectare 518.992	hectare 64.870 (13%)	hectare 194.530 (37%)	hectare 101.600 (20%)	hectare 93.000 (18%)	hectare 64.992 (12%)	76.029
Bonthain	415.754	37.410 (9)	211.990 (51)	19.813 (5)	62.000 (16)	84.541 (19)	62.761
Bone	885.157	143.830 (16)	431.470 (49)	128.343 (15)	114.900 (13)	66.314 (7)	135.038
Pare-Pare	639.845	223.940 (33)	223.860 (33)	76.450 (12)	50.000 (8)	65.597 (14)	89.741
	2.459.748	470.050 (19)	1.061.850 (43)	326.206 (13)	319.900 (13)	281.444 (12)	363.569

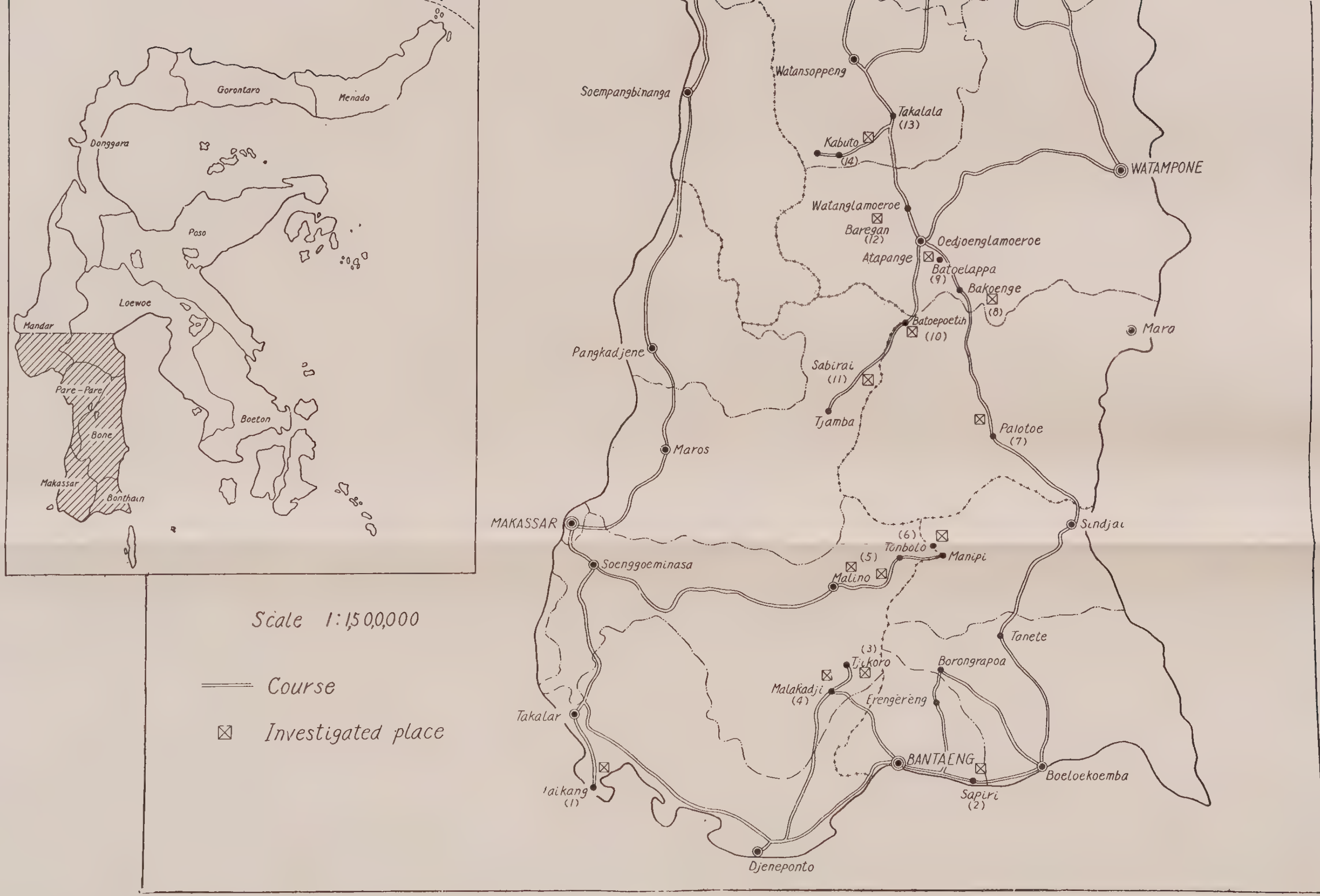
Pare, the natural grassland and the forest land proportionate 43% and 18% respectively against the 39% of the total acreage of the upland farm. In other words, there is the grassland of 1,061,000 hectares as against the upland farm of 686,000 hectares.

3. General circumstances of agriculture

The staple land for the production of provisions is located in the areas of the Makassar Peninsula. Soils of the land are generally the red-brown or dark brown heavy clay and are rather high in productivity. However, as agriculture is followed the depredatory agriculture method, the inhabitants move to one place to another 3 to 4 years after reclamation. There are frequently seen upland farm lands which lie fallow or are deserted in the neighbourhood of settlements. Not that they are indifferent utterly to the maintenance of soil fertility, some apply the remains of food, ashes of plants and trees and excrements of sea birds to their



Mamasa
PALOPO
Makale
Paso
Polewali
Mapili
MADJENE
Enrekang
(24)
Bera
S. Sadang
Kabere
(22)
Malimpang
(23)
Maiwa
(21)
Pinrang
Siwa
(20)
Baroekkoe
(19)
Binroro
Kera
Rapang
(15)
Larisen
Pangkadjene
Lantjirang
Tanroetedong
(18)
Anabanoea
Ronka
Bolamalimpong
Danau Sidenreng
(25)
PARE-PARE
Masepe
(26)
Biloka
Danau Tempe
Atapange
Mege
(16)
Ponrangriase
Impa
Sengkang
Ladjaroko
Batoe-Batoe
(27)
Paniki
(17)
Pompanoea
Makassar
Peninsula
Selebes Island


Gorontaro
Menado
Donggara
Poso
Loewoe
Mandar
Pare-Pare
Bone
Boeton
Makassar
Bonthain
Soempangbinanga
Watansoppeng
Takalala
(13)
Kabuto
(14)
WATAMPONE
Watanglamoeroe
Baregan
(12)
Oedjoenglamoeroe
Atapange
Batoelappa
(9)
Bakoenge
(8)
Batoepoetih
(10)
Maro
Pangkadjene
Sabirai
(11)
Tjamba
Palotoe
(7)
Maros
MAKASSAR
Sindjai
(6)
Tonbolo
(5)
Manipi
Soenggoeminasa
Malino
Scale 1:1,500,000
Tanete
(3)
Tjikoro
Borongrapoa
Course
Malakadji
(4)
Erengereng
Takalar
Investigated place
BANTAENG
Boeloekoemba
Iaikang
(1)
Sapiri
(2)
Djeneponto

farms. In general, the inhabitants install a simple livestock stable in the site of cultivated lands and utilize excretions of livestock to the land by moving livestock ocassionaly or grazing in the upland farms in translocating them from the grassland. The grazing of livestock in the site of cultivated lands are prevalently taken place and the animals feed stems and leaves of crop plants after harvested or natural grasses in the lands. Accordingly, it may be said a sort of the grain-grass farming It is of a great interest that the admittance of coming in and out of livestock even in the lands of others is given conventionally.

As mentioned above, although the cultivation of crops is limited to the rainy season and the land is fallowed during the arid season, an irrigation work is constructed for the area of 150,000 hectares (about one-third of the total acreage of paddy fields), where the double crop a year is possible.

The agriculture population is assumed to be about 55%, 2.000,000 persons, of the total population in the southern part of Selebes Island. However, as women and children are not engaged in out-door labor except the planting and harvesting seasons and the potential man-power is estimated less than 1,000,000 the agricultural population should be considerably small.

The main agricultural products are rice and corns as the staple food, and abundant in coconut and cassava, besides which the pulse are planted as the secondary crop after the harvest of rice plants and german millet, deccangrass and kaoliang are cultivated on the cool hights locally.

The rice plants for cultivation are for the most part paddy rice plants. Although in general the single crop a year is prevalent, a considerable surplus of product can be seen in the Macassar Peninsula. Although the irrigated nursery bed is installed at large, the dry nursery bed is in use in the Bone district irregular in rainfall and the direct sowing method in the areas scanty in rainfall. Varieties of paddy rice plants are extremely multiple and the cultivation methods are primitive.

Most of corns are cultivated in the upland farm, but some are planted as the secondary crop in paddy fields. The duration of cultivation is for three months from October to January of the succeeding year, but sometimes the mixed cultivation of cassava and potatoes is taken place. Not the direct sowing method but the method of transplantation of seedlings from the nuresry bed about one week after germination is being practiced very widely.

The plantation acreage of the staple agricultural products and the yield are tabulated in Table 3.

4. Outline of livestock raising

The number of livestocks subject to 1943's investigation is given in Table 4. About 70% of the number of livestocks in all areas be fed in the southern Selebes Iisland. When computed in the unit of one square kilometers, the large-type cattle numbers 21.3 as against 4.1 in Japan in the same year, showing a consider-

Table 3. Yields and cultivated area of main crops in Southern Selebes. 1940.

	Area	Yield
	hectare	ton
Paddy-Rice	369.000	609.517
Upland rice	54.896	107.476
Corn	197.798	586.511
Cassava	25.138	200.535
Pulse	10.532	10.354
Potato	3.826	15.645
Peanut	3.817	12.705
Tabacco	1.782	—
total	666.789	

Table 4. Number of livestock in Southern Selebes. 1943.

	Horse	Cattle	Baffalo	Pig	Goat
Makassar	31.213	2.472	112.166	3.299	38.151
Bonthain	25.459	719	36.849	223	17.305
Bone	75.488	5.298	139.606	302	24.012
Pare-Pare	22.761	8.175	65.389	1.979	29.715
Mandar	4.027	1.317	11.110	8.967	17.859
Loenoe	5.556	2.092	65.150	88.620	5.210
Boeton	4.718	2.278	15.136	337	19.447
total	169.919	22.351	445.406	103.727	151.699

able density of livestock population. However, this figure is smaller as compared with 43.6 in Java Island and 50.7 in Bali Island respectively. Moreover, the grazing method in the areas of Selebes Island differs remarkably from these two islands, as both of Java and Bali Islands are not provided with the same vast natural grassland as in Selebes Island and leaves of crop plants and trees or grasses of fallow lands are the main forage for livestock. Consequently, it may be said that the future development of livestock raising is very prospective.

Horses are all small-type blended the indigenous species with Mongolian and Arabic bloods. Although horses are used for labor works, they are mainly used for riding, loading and horse-carts but are scarcely employed for the cultivation of farms. Following a primitive feeding method, mares arc grazed in a natural grassland or paddy fields throughout the year and stallions are under the tethered grazing near the houses for the convenience of draft use. In addition, the forage depends mostly upon natural grasses. The propagation of cattle is carried out by free copulation, but it is conventional to release stallions into the herd of mares under grazing.

In spite of the fact that the northern Selebes Island has been raising cattle since a long time ago, the raising of cattle in the southern part of Selebes Island was started recently by importing them from Bali Island. These cattle, however,

are used for the cultivation of dry rice fields and the production of meat is attached the secondary importance.

Having been raised for a long time, baffalos in the island are regarded as the same species as in the East Indies. In addition to the use for cultivation, they are eaten by the inhabitants and about 60% of the demand for meat is the baffalo's meat. The raising of baffalos depends mostly upon grazing.

In relationship with religion, swine are exclusively raised only by the Tradja tribe living in the mountains in the northern part of Selebes Island and Chinese-Malayans. As most of the inhabitants are Mohammedans, they do not raise swine regarding them as an impure animal. The indigenous species of swine being raised by the Tradja tribe is a small and late maturing species and is said that the number of days for raising requires about four times that of the early maturing species. In the urban districts the Chinese-Malayans are raising numerously swine bled mixedly with Chinese swine, Yorkshire species and Bali species.

Excepting the district of the Tradja tribe, goats are raised in all districts. The indigenous species is a small and brown one, both sexes have horns. In the recent years, Etawab species has been imported for the improvement of goat-raising, and all of them are served as meat.

The actual state of affairs of livestock is obscure. This may be attributed to the fact that the livestock has been long subject to taxation and the inhabitants tend to hide the accurate number of them. On the other hand, the prevalence of free copulation for propagation brings about the difficulty to know the exact number of livestock. The principal purpose to raise livestock may be said to accumulate the assets. Accordingly, the difference of the rich and the poor is decided by number of livestock in addition to the lands owned by the inhabitants. The inhabitants do scarcely possess the desire for the accumulation of cash, because there are rare opportunities to own cash and the economic daily life is based on the bartering system or the exchange of labor and commodities with the exception of the urban districts. Although most of farmer raise livestock, the farmer which own the large-type domestic animals are extremely small in number agaist our expectation, as a reason for the conspicuous difference btween the rich and the poor. For instance, in a certain area of the Pare-Pare district the farmer owning no large-type livestock showed as much as about 85% and there were some settlements which indicated 75% to 90%. Meanwhile, it was 74% in the Bone district. As mentioned above, the large-type livestock are distributed locally.

5. Productivity of forage

As all large-type livestock are grazed in a natural grassland or in a upland farm after harvesting and the small-type livestock are grazed tethering in a small natural grassland around the settlements, forage is not produced artificially and

only the diversion ot part of provisions for forage can be seen sometimes. Accordingly, if the seasonal change from the arid season to the rainy season should be prolonged, a large number of livestock would be starved to death from the immediate shortage of forage. Despite of the repetition of such an damage, the preservation of forage has not been observed by the inhabitants. It may safely be said that the way of livestock-farming in the island is really at the primitive stage.

6. Grazing of livestock

(i). Grazing in the natural grassland

Being no systematic, livestock owned by the individual of the inhabitants are merely grazed in natural grassland possessed by settlements or individually. There is seen no adjustment of grazing in view of the productivity of grasses in the natural grassland. Accordingly, the shortage of grasses owing to the climatic condition is considered to cause the starvation of a large number of livestock. Although it is a popular scene to see the slow movement of baffalos in a herd under the direction of shepherd-boys riding ahead the herd, these shepherd-boys are assigned only to prevent them from missing or invading into a grassland owned by others and upland farms. However, no watch-men are assigned in case of grazing of the herd of horses on account of their limited range of movement. On the other hand, baffalos are said to move as far as over 40 kilometers in a day with a strong rambling disposition. Therefore, grazing of horses is taken place day and night, while baffalos are grazed only in the day-time and kept in the settlement in the night-time. The grassland around the settlement presents a well-mowed lawn without exception and the height of grass becomes taller almost proportionately to the distance from the settlement. Although such a plant succession can be seen in *Bokuya* in Japan under the rough management, it is observable everywhere in Selebes Island.

(ii). Grazing in the cultivated land

The begining of the arid season falls on the begining of the harvesting stage, and after harvested agricultural products livestock in the natural grassland are customarily moved to the upland farm. One of the purposes of this custom aims to increase fertility of the upland farm by excretions of the livestock. Besides, although not enough in quantity, the remains of still greenish stems and leaves of crops and the growth of grasses can temporize the shortage of forage at that time. Livestock in the upland farm are moved back again to the grassland at the time when vitality of grasses in the natural grassland is recovered.

III. Outline of the Grassland

1. Causes for the formation of grassland

As shown in Table 2, there is a natural grassland of about 1,061,000 hectares which is larger in acreage than the upland farm and the forest. The cause for the

formation of such a vast natural grassland is considered attributable to the primitive agricultural management by the local inhabitants. Forests are converted into a cultivated land by cutting and burning, and after the inhabitants cultivated crops for about 3 to 4 years, with the degradation of soil fertility, they move to another land showing the so-called brand-farming method. The author observed burinng of forests and visited a number of deserted farm lands. These deserted farms are converted into a grassland within a year.

As the land of high temperature and humidity, the grassland should become a forest land growing shrubs and tall trees if it were left untoched, the forest land is limited to humid lands along the valley region presumably due to the branding procedure. There is seen a prevalent custom to burn off the grassland at the end of the arid season. In short, it may be said that the natural grassland in Selebes Island is formed as the result of the unsystematic agricultural management and is maintained by the branding method.

2. Outline of vegetation in the natural grassland.

The present investigation was carried out in the middle of the arid season from June to July. In this work, the author was forced to make a round trip of the aforesaid peninsula for only 25 days because of my visit to the island during the war. Accordingly, the investigation was limited to a general observation. Grasses were grown luxuriantly during the rainy season and the fruiting stage fell on the arid season as these grasses bloomed at the end of the rainy season. Consequently, it was extremely difficult and sometimes impossible to discriminate grasses ravaged by a long term grazing of livestock, although the investigation was made opportunely. The varieties tabulated in Table 5 inculde some sixty plants which were discriminated in the investigation. However, as no remarkable difference of distribution of these varieties can be considered by geographical location in the peninsula, the tabulated plants may be considered to be distributed almost universally in the peninsula. The notation used in this table signifies a=abundant, m=moderate and f=few. As to whether the composition of respective grasslands can be known by this table, it may be possible to comprehend generally, but this work did not cover the fields concerned in detail.

In the collected grasses there were included new varieties, some of which were named by Dr. Jisaburo Ohwi. As the specimens (dried leaves) which were brought back to Japan with difficulty were not good ones, it is regretable for the author to be unable to explain more clearly. Although there were many plants belongs to *Cyperaceae* palatable for baffalos, they could not have been collected being unable to discriminate them. However, the presence of a large number of *Cyperaceae* in the grasslands differred considerably from the case of natural grasslands in Japan.

Avoiding the fractional explanation as much as possible, the result of the investigation will be summarized as follows.

(i) Southern natural grassland

The natural grasslands in Makassar and Bontaing states were distributed on Mt. Lompo-Batang and its foot. There were seen plain natural grasslands in Laikang (1 numbered on the figure) 50 km south of Makassar city and Sapiri (2) 15 km east of Bantaing city and mountainous natural grassland in Tjikoro (3), Malakadji (4), Malino (5) and Tonbolo (6) on Mt. Lampo-batang. The natural grassland in Laikang presented dried and solidified dark grey soils which were cracked so finely as to present exfoliation. In spite of such soil conditions, grasses remained greenish, where a large number of livestock were being grazed. Although there were withered grasses, they were not distinguishable. Grasses which remained greenish were small-type plants with creeping culms such as *Cynodone dactylon* and *Panicum indicum* and cyperaceous plants. These plants were considered well resistant to grazing of livestock and aridity. The natural grassland around Sapiri is a vast land of 3,000–4,000 hectares in estimate. Utility of the grassland was low due to its vast acreage and there were observed many tall grasses which were left half-eaten by livestock. In other words, the natural grassland may be the so-called long-grass type grassland and the aforesaid natural grassland in Laikang the so-called short-grass type grassland. Dominant long-grasses were *Heteropogon contortus, Bothriocloa glabra* and *Sorghum ntidum*.

In Tjikoro settlement halfway up on the south Mt. Lampo-Batang there was a dairy farm managed by a German in pre-war days, in which the author observed the luxuriant growth of palatable plants for livestock presumably resultant from a good care of the grassland. On the contrary, the natural grassland in the vicinity of Malakadji in free use by the inhabitants was a lawn-type grassland where grasses were eaten out mostly by livestack and were too short to be identified. The grasses classified were *Pseudopogonatherum tripicatum, Arthraxon microphyllus* and *Ischaemum timorense* as dominant species. Besides, in the places where livestock tended to gather were abundant in *Rhaphis aciculatus* and *Ischaemum timorense*. These plants seemed to have strong resistivity to grazing of livestock.

Malino and Tombolo natural grasslands are located on the mountainous region 1,000–1300 m above the sea level, where the dominance of *Ischaemum timorense* was conspicuous. Although of *Ischaemum* spp. there were also erect *Ischaemum aristatum* and somewhat geniculate *Ischaemum beccarii*, *Ischaemum timorense* which was geniculate and produced a number of adventitious roots from nodes was seemed to be more adaptable to the grazing land. In addition, there was observed a grassland dominant of *Themeda triander*. As the character of these grasslands, there was observed none of *Cyperaceae* while presenting the presence of *Pteridium* species.

(ii) Central natural grassland

There is a vast natural grassland in the central district ranging from the

northern foot of Mt. Lompo-Batang to the basal part of the peninsula. Settlements and upland farms present an outlook of being scattered in the enclosure of this vast area of the grassland.

What attracted first the author's attention was the formation of *Arang-Arang grassland* which is called one of peculiar phenomena of grassland in the southeast Asian islands. Although the name of *Arang-Arang* is the common name for either *Imperata exaltata* or *Imperata cylindrica*, it is uncertain whether the former or the latter signifies it. It was conceived that those which grew in this natural grassland were mainly *Imperata cylindrica* (supposing that is *Imperata cylindrica* in this paper). At any rate, according to the present investigation, the dominant degree of *Imperata cylindrica* (grass height : about 0.7 cm) was 4, and that of *Pasparum scrobiculatum* and *Cyperaceae* was 3 and 2 respectively, and there were also observed areas in the grassland overwhelmingly dominant *Imperata cylindrica*. However there had been rarely seen no sites where grazing of livestock was taken place. According to the information obtained there, the solidification of stems of *Imperata cylindrica* with the lapse of time becomes unsuitable for grazing of livestock, so that branding of grasses is usually given to the grassland at the end of the arid season to utilize new sprouting buds. As these new buds are palatable for deer, the natives hunt deer frequently in the burned grassland without grazing livestock. For this purpose, *Arang-Arang natural grassland* seemed to have been protected particularly. Therefore, natural grasslands to this type may tend to increase more and more.

In general, baffalos frequented the grasslands in the vicinity of settlements in the morning and evening in addition to grazing of small-type livestock, showing a high utility of the grasslands so as to present short grasses as in a well mowed lawn as the result of grazing. In these natural grasslands, being similar to the case in the southern grasslands, there were observed short-grass type plants and creeping plants such as *Eulalia Leschenaultianna*, *Panicum indicum* and *Rhaphis aciculatus*. Such a finding may prove propriety to combine grazing with the appearance of these grasses.

No burning would be taken place in natural grasslands where such short-grass type plants are dominant. The burning method was said applied chiefly to the long-grass type grassland to utilize new buds by burning off withered stems and leaves in the arid season.

As other characteristic physiognomy standing trees were scarcely seen in the natural grassland and forest districts were only located in the vicinity of a settlement or a valley. In consideration of climatic conditions of this district, the reason for having no standing trees in the natural grassland can be attributed entirely to the application of the burning method, not to climatic conditions.

When generalized the species of grasses in this district, *Rottboellia exaltata*, *Heteropogon contortus* and *Imperata cylindrica* were comparatively dominant and

followed by *Sorghum nitidum, Apluda mutica* and *Themeda triander*. Partially, there was observed the growth of *Eulalia leschenaultianna, Panicum indicum, Schizachyrium fragile* and *Rhaphis aciculatus*. One of noteworthy findings was that there were observed several species belonges to the leguminose plants in the vicinity of Kakuto (14) and Takalala (13) near the northern part of the central natural grassland. Because *Leguminosae* were scarecly found in the southern natural grassland and the southern part of the central natural grassland.

(iii). Northern natural grassland

Near the northern part of the peninsula, there are two lakes, that is, the Lake Tempe and the Lake Sidenren. Being prosperous in fishing business in these lakes in addition to the deployment of upland farms along the banks of the lakes, the population in the areas is dense. In particular a vast natural grassland is linked with the mountainous district in Enrekang from the east of these lakes to the north, while the natural grassland encloses the well-reclaimed upland farms. Even "*Kusasenri*" (expression of a vast grassland) in the northern Kyushu in Japan can not compete with this natural grassland at such a large scale beyond the estimation by a look.

Firstly, the eastern, northern and western areas centering the two lakes shall be described. The investigation was initiated in the eastern natural grassland area by going southwards from Siwa settlement on the eastern coast to study the natural grassland areas in the vicinity of Kera, Larisen and Ronka settlements (15). In advancing southwards further, Mege (16) and Paniki (17) were studied. Although no particular variance in species of grasses was seen, the natural grassland with a vast acreage was abundant in long-grass type species owing to low frequency of utilization. In the area where the number of livestock was great in comparison with the acreage of grassland, the long-grass type species became shortened and geniculate grasses such as *Pognatherum crinitum* and creeping type grasses such as *Cynodon arcuatus* and *Zoysia tenuifolia* were grown. *Ischaemum timorense*, a geniculate type grass, formed a large stub of some 30 cm in dia. at intervals of stubs spacing in the row in which washed soils created a deep ditch. Moreover, the grasses was eaten out by livestock to remain only 4 ~5 cm long. Such being the case, a natural grassland taking a shape of an endless arrangement of semi-circular cylinders in the top region ranged in a vast acreage. The presentation of such an attractive view of the natural grassland may be attributed to the indication that only grass species resistive to grazing of livestock afforded to remain in the grazing land. Except this grassland, in general, the natural grassland was abundant in *Rottboellia exaltata, Pognatherum crinitum, Zoysia tenuifolia* and *Cyperaceae*.

Linked with this eastern natural grassland, there is a vast natural grassland acrossing the peninsula reaching so far as the mountainous district in the vicinity of Enrekang north of the connecting line of Balamalimpang, Tanroetedong,

Table 5. Grasses and its frequency of the na

Place name of researched / Name of grass	(1) Laikang	(2) Sapiri	(3) Tjikoro	(4) Malakadji	(5) Malino	(6) Tombolo	(7) Polotoe	(8) Bukoenge
Graminae								
Andropogon brevius Swartz.			m				f	
Apluda mutica L.					f			f
Arthraxon microphyllus Hoch.			a	f		f		
Arundinella fuscata Nees.			f		m	m		
Arundinella setosa Trin.								
Bothriocloa glabra A. Camus var. perfectior Ohwi.	f	a						
Bothriocloa parviflora Ohwi.								
Brachiaria distachya A. Camus.		f						
Brachiaria reptans Gardn. et. Hubb.		f						
Chionachne Koenigii Thw.								
Cynodon arcuatus Presl.								
Cynodon dactylon Pers.	m							
Dactyloctenium aegyptium Richt.								f
Digltaria chinensis Hornem.			m					
Dimeria arnithopoda Trin.			f					
Eragrostis elongata Jacq.								
Eragrostis nutans Nees.								
Eriochloa procera Habbard.		f						
Eulalia amdura Ohwi.								
Eulalia Leschenaultianna Ohwi.				a				
Heteropogon contortus Beauv.		a						
Heteropogon triticeus Stapf.								
Imperata cylindrica Beauv.					f	m	a	
Ischaemum aristatum L.								m
Ischaemum Beccarii Hack.					a	a		
Ischaemum timorense Kunth.		f		a				
Leptochloa filiformis R. & S.								
Ophiuros exaltatus O. K.								m
Panicum indicum L.	a			m				f
Panicum plieatum Lamk.			f					
Panicum repense Linn.						f		
Panicum suishaense Hayata.								
Paspalidium punctatum A. Camus.								
Paspalum conjugatunz Linn. Presl.								
Paspalum scrobiculatum Linn. Presl.			m			f	m	
Polytoca digitata Henr.								
Pognatherum crinitum Beauv.								
Pseudopogonatherum tripicatum Ohwi.			a	a	m	m		m
Rhaphis aciculatus Honda.			f	f				
Rottboellia exaltata L. F.								a
Schima nervosum Stapf.								
Schizachyrium fragile A. Camus.								a
Setaria luteseens Hubbard.								
Setaria viridis Beauv.								
Setaria viridis Beauv. var. purpurascens Maxim.								
Sorghum nitidum Pers. var. nitidum Ohwi.		a			f	f		a
Sorghum nitidum Pers. var. parvifloum Ohwi.								
Sporobolus elongatus R. Brown.						f		
Thmeda triander Forsk.		f	f	f	a	a		
Tricholaena rosea Schrad.			f					
Urochloa paspalorden Prex.		f						
Zoysia tenuifolia Willd.								
Leguminosae								
Albizzia procera Benth.								
Cantharospermum scarabaeoides Baill.								
Desmodium biarticulatum		f					f	
Desmodium heterocarpon DC.								
Desmodium triflorum DC.								
Lespedeza (?)								
Pueraria phaseoloides Benth.								
Tephrosia vestita Vogel.								
Uraria logopodioides DC.								
Polypodiaceae								
Pteridium					m	m		
Cyperaceae								
Cyperus and others.	m	m	m			m	m	m

tural grassland in the Makassar peninsula.

(9) Batoelappa	(10) Batoepoetih	(11) Sabirai	(12) Baregan	(13) Takalala	(14) Kabuto	(15) Larisen	(16) Mege	(17) Paniki	(18) Anabanoea	(19) Binroro	(20) Baroekkoe	(21) Maiwa	(22) Kabere	(23) Malimrang	(24) Bera	(25) Pare Pare	(26) Biloka	(27) Batoe-Batoe	Frequency %
																			0.07
		m	f	f	m						f				a	f			0.33
				f	f														0.19
																f			0.11
	f	f									a								0.15
						f	f		f										0.19
								f			f								0.07
								f		f		f							0.19
														f					0.04
					f									f		f			0.11
				f			m		m									a	0.15
															f				0.07
												f							0.07
	f								f			m			f				0.19
										f									0.04
										m									0.04
																			0.04
							m												0.07
													f						0.04
a			f									a			a	f	a		0.26
	a	a	m	f	m					f			f			f	a	a	0.41
									f	f		f	f	m	f	f	f		0.30
	f	f	a	a	f	f			f	f		a	a	f	m	f		f	0.63
						a						f		a	f				0.19
																			0.07
								a	m	m	f					a	f		0.30
															f				0.04
																			0.04
a								f											0.19
																			0.04
																			0.04
										f	a								0.07
							m	f			f					f			0.15
f	f								f			m		f	f				0.22
				f			f	f	f	m		m		f	f				0.41
												f							0.04
							a	f											0.07
												f	f	m		f	f		0.37
f	f								m			a	f	f	m	m	f	f	0.44
	a	a	m	a	m	a		a	m	m	f	f	t		m	m	f	a	0.63
																f			0.04
		f									a								0.11
										f									0.04
												f		f	f	f			0.15
																			0.07
	m		m			f						f	f			f	f		0.33
																f		m	0.07
															f				0.07
f	m				f				f							f			0.37
																			0.04
																			0.04
			f				a	f	m	a	m		f		f				0.30
															f				0.04
				f	f														0.07
	f			f	f				f	f		f		f	f		f	f	0.44
										f									0.04
				f	f					m	m	a	f		m	f			0.30
			f	f															0.07
			f	f	f										f				0.11
										f									0.04
				f	f														0.07
																			0.07
m		f		f	f	a	a	a	m	m	m	f		m	f				0.70

Rapang and Pinrang settlements, located north of the Lakes Sidenren and Tempe. The author made the investigation at 7 stations in the natural grassland, but the exploration by riding on a horse in the hinterland was limited considerably on account of the schedule restricted in a short period. In the survey grassland, hill-type grassland were abundant with the exception of mountain-type grassland in Bera settlement (24).

The natural grassland was being utilized heavily, in which some of *Leguminosae* were observed differently from the eastern natural grassland. The effect of grazing upon the variation of vegetation was similarly seen in the other grassland, and there were seen grassland areas characterized with the peculiar type of *Ischaemum timorense*. The result of the investigation on the grasses grown in the sites of deserted farm lands is summarized as follows.

Plant community 1.

Eragrostis elongata; *Eragrostis nutans*; *Heteropogon triticeus*; *Rottboellia exaltata*; *Brachiaria distachya*; *Paspalum scrobiculatum*; *Zoysia tenuifolia*; *Desmodium triflorum*.

Plant community 2. (site of cotton cultivated land)

Setaria luteseens; *Rottboellia exaltata*; *Eragrostis elongata*; *Brachiaria distachya*; *Panicum suishaense*; *Imperata cylindrica*; *Paspalum scrobiculatum*; *Heteropogon contortus*; *Heteropogon triticeus*; *Desmodium biarticulatum*; *Desmodium triflorum*, *Cyperaceae*.

Such a secondary vegetation is useful to know the plant succession of natural grasslands. Most of the above-mentioned grasses are belonged to the bunch grass type and those which have rhizomes and creeping culms are limited to a part of these species. This fact suggests that vegetation of the natural grassland in the island be composed of grasses of the bunch grass type if no distrubance is occurred. Such a tendency as seen in the grassland is the very same as in the natural grassland in Japan.

In advancing northwards from Rapang to Maiwa (21) and Kabere (22), the natural grassland underwent the transition from the hill-type natural grassland to the mountain-type natural grassland gradually, where *Imperata cylindrica* was seen dominantly and in the vicinity of Kabere the *Arang-Arang grassland* in the formation of pure *Imperata-community* was seen. In general, the plant community was the one mixed with *Ischaemum aristatum*, *Rottboellia exaltata* and *Sorghum nitidum* or sometimes *Cyperaceae*. However, as *Imperata cylindrica* tended to grow not distributively throughout the entire areas but concentrically in the natural grassland, the natural grassland areas deficient of *Inperata cylindrica* were natural grasslands dominant in *Rottboellia exaltata* and *Ischaemum aristatum*. etc.. As mentioned already, *Imperata cylindrica* was protected more or less for the purpose of using its young buds for deer hunting or using for thatching the roof. Accordingly, evidences of migration of livestock were scarecely seen in the

Arang-Arang grassland in this district, but the grassland areas where *Imperata cylindrica* was not grown were affected strongly by grazing of livestock. In Japan such a dominant growth of *Imperata cylindrica* in *Bokuya* of a vast acreage can not be seen, though the plant is observable widely. If protection be made as in Selebes Island, the formation of a natural grassland dominated by *Imperata cyiindrica* may be materialized in Japan as well.

There is a steep mountainous natural grassland in the vicinity of Bera (24) settlement after crossing the river Sadang which flows into the Makassar Sea, north of Pinrang. The natural grassland presented a peculiar type formation as compared with other natural grasslands in the peninsula, being abundant in shrubs. No investigations were made on the shrubs and any peculiar grasses were not observed. It was seen only that *Cyperaceae* was limited its growth to the low land below the middle hight of the mountain.

A strip of a natural grassland is deployed in the inter-district between Pare-Pare city and the Lakes Sidenren and Tempe. The southern end of the natural grassland is connected with the above-mentioned central natural grassland. As the result of investigations at 3 stations, that is, Prae-Pare (25), Biloka (26) and Batoe-Batoe (27), there were observed natural grassland areas abundant in *Rottboellia exaltata*, and *Ischaemum timorense.*

An interesting variation of vegetation was appreciated in the natural grassland utilized for the inhabitants in Biloka settlement. The natural grassland is located west of the settlement and reached the range Latimodjong near the coast line of the Makassar Sea. Although the grassland near the settlement showed grasses eaten almost completely by livestock as a well-mown lawn, as stated before, the gradual growth of plant height was seen with the distance from the settlement and the dense growth of well-grown grasses was observed in the mountainous zone as far apart as some 10 kilometers. In other words, the discrimination of grasses was extremely difficult in the neighbourhood of the village because of the ravage of grasses by grazing, but there were observed *Ischaemum timorense, Heteropogon contortus*, *Eulalia leschenaultianna* and *Rhaphis aciculatus*. Both of *Eulalia leschenaultianna* and *Rhaphis aciculatus* are the short grass type and characterized with creeping growth, while *Ischaemum timorense* is the geniculate type grass and resistive to grazing. Accordingly, resistive grasses to grazing were remained in the neighbourhood of the settlement. However, being distant from the settlement *Rhaphis aciculatus* and *Eulalia leschenaultianna* became decreased gradually, while the appearance of *Heteropogon contortus, Heteropogon triticeus, Rottboellia exaltata* or *Desmodium biarticulatum* was observed and the ravaged degrees by livestock became diminished. When entered further into the moutainous zone, there was observed a natural grassland area abundant in *Heteropogon contortus*. In addition to the difference of grass height, species of grasses varied evidently between the neighbourhood of the settelement and distant places from

it. Accordingly, it may be said that the natural grassland of the short-grasstype species (or the natural grassland of grasses resistive to grazing. Hereafter called the short-grasstype grassland on account of abundance of short-grasstype species), the grassland blended long and short-grasstype species and the grassland of the long-grass type species are deployed concentrically centering around the village (called the concentric plant succession). Such a plant succession presents an arrangement of various plant successions in other grasslands at one district. Although such a variation of plant succession in a series can be conjectured readily from the above-mentioned vegetation types in the respective natural grasslands, the effect of grazing of livestock upon vegetation may be led to an evident conclusion in view of the orderly arrangement of plant succesion in the same natural grassland. The aforesaid natural grassland abundant in *Ischaemum timorense* may be regarded as one of a transformation of this concentric plant succession. Because the dominance of only this grass may be considered sometimes, as *Ischaemum timorense* was observed for the most part in the short grass-type grasslands.

With regard to this respect, a problem of another plant succession shall be discussed on the appearance process of the *Arang-Arang grasssland.* Observed in the long-grass type grassland generally, *Imperata cylindrica* was seen nowhere in the above-mentioned concentric plant succession or in other short-grass type grasslands and their connecting part. Therefore, resistivity of this grass to grazing may not be so large conceivably. It seems necessary to protect the species more or less from grazing, in order to have its thick growth in the natural grassland. The possibility of substantiation of the grassland dominated by this grass species can be considered in view of the fact that grazing of livestock became less frequent with the distance from the settlement and the garss was not so palatable for livestock in addition to the protection of this grass species as a deer hunting grassland. Although the reason for the formation of the *Arang-Arang grassland* could not be clarified beyond the abovementioned description, it was held true that there was a sere of succession where a natural grassland dominated by *Imperata cylindrica* was seen other than the sere of succession shown in the concentric plant succession. However, the relationship of this sere of succession to the above-mentioned concentric plant succession is obscure. Though not so evident, the reason that the dominance of *Imperata cylindrica* can not be seen in *Bokuya* of Japan in spite of its presence everywhere may be attributed to a weak resitivity of the grass to grazing of livestock and unadaptability to the mountainous land. In addition, this may be due to the fact that *Miscanthus sinensis*, a dominant propagative species, constitutes the long-grasstype grassland with which *Imperata cylindrica* can not gain competition. As for the sere of the concentric plant succession in Japan, the arrangement of the grassland is usually comprised of the short grass-type grassland abundant in *Zoysia japonica*

with creeping culms in the center and the long grass-type grassland dominated by *Miscanthus sinensis* in the outside, between which the mixed type grassland of the above two grasses can be seen.

As the outline of natural grasslands in respective places were summarized above, additional important findings shall be mentioned hereafter. As *Graminae*, there were referred to *Rottboellia exaltata* (frequency of appearance : 63%), *Imperata cylindrica* (63%), *Rhaphis aciculata* (44%), *Heteropogon contorsus* (41 %), *Paspalum scrobiculatum* (41%), *Themeda triander* (37%), *Pseudopogonatherum tripicatum* (37%), *Sorghum nitidium Pers. var. nitidum* (33%), *Heteropogon triticeus* (30%), *Ischaemum timorense* (30%) and *Zoysia tenuifolia* (30%). As *Leguminoseae*, the distribution of *Desmodium biarticulatum* (44%) *and Desmodium triflolia* (30%) was conspicuous. Of course, being small in quantity, the distribution of *Leguminoseae* was limited to local spots in the central and northern natural grasslands. Besides, several species belonged to *Cyperaceae* were observed widely in the flat natural grassland except the mountainous natural grassland, being palatable for baffalos.

At large, grasses belonged to *Graminae* and *Cyperceae* were the main constituents of the natural grasslands, while grasses belonged to other plant families were rarely seen. The scarcity of grasses belonged to *Compositae* and *Eufilicales*, as compared with *Bokuya* in Japan, is one of the different aspects.

Subsequently, the effect of grazing upon the vegetational succession shall be mentioned. The natural grassland which came into existence as the result of cutting of forests or the desertion of upland farms was the long grass-type grassland. However, the dominant grass species in the grassland had not been clarified as compared with the *Miscanthus type grassland* in Japan in which *Miscanthus sinensis* is overwhelmingly dominant. But the formation of the long grass-type grassland is evident in view of the vegetation of the aforesaid deserted upland farms. The variation of vegetation in these long-grass type grasslands disturbed by grazing of livestock may be conjectured approximately by making the comparative study on the difference of grassland vegetations in different areas. Beyond that, the most evident clarification can be given by the above-mentioned concentric plant succession. As the degrees of grazing became intensified with the approach to the settlement, the relationship between the intensity of grazing and the variation of grass species may illustrate the process of plant succession. In other words, the long grass-type grasses became dominant when the intensity of grazing is in a low extent, while grasses resistive to grazing came to appear gradually. *Ischaemum timorense* having a strong resistivity to grazing appeared as a component of the short-grass type grassland in the concentric plant succession, but formed sometimes the *Ischaemum* dominant grassland by itself. Accordingly the natural grassland dominated by a single grass species can be regarded as one of the transformations in the concentric plant succession, but there were the

natural grassland dominated by *Imperata cylindrica* in other than the said sere of succession. That is the grassland called the *Arang-Arang grassland.* The natural grassland of this type was not developped in the vicinity of settlements, but was seen in the area distant from them. In other words, this grassland was seen in the places where the intensity of grazing became reduced. In view of the secondary grassland at the site of an upland farm, it may be said that *Imperata cylindrica* is not the grass migrated originally into the new land but the one migrated at the time when the long-grass type species became deteriorated by grazing of livestock after which time gained its propagation gradually. As stated already, however, the protection of the grass and unpalatability for livestock may be the condition for its dominance.

In short, in Selebes Island there are considered two processes of plant succession. In other words, divided from the long-grass type grassland, one may direct towads the formation of the grassland dominated by *Imperata cylindrica* and the other towards the formation of the short-grass type grassland. However, the relationship between these two processes is not made clear in this paper.

In the natural grassland where intensive grazing was taken place, the following grasses tended to grow prevalently. That is, *Rhaphis aciculatus, Zoysia tenuifolia, Bothriocloa globra A. Camus var. perfectior. Cynodon arcuatus, Cynodon dactylon, Dactyloctenium aegyptium, Eulalia leschenaultianna, Eulalia amaura* and *Panicum indicum.* These grasses were comparatively short in plant height and have creeping culms, or rhizomes and stems diverged adventitious roots geniculately, showing resistivity to garzing. Of the long grass-type species, *Imperata cylindrica* had short rhizomes, while *Ischaemum timorense* were geniculate and diverged adventitious roots showing resistivity to grazing.

IV. Summary

The investigation on natural grasslands in the Makassar Peninsula of Selebes Island was made from June to July, 1944.

The total acreage of the natural grassland in the peninsula was about 1,061,-000 hectares (about 43% of the total land acreage), being larger than the acreage of upland farms (39%) and that of forests (18%).

Of the livestock raised, large-type livestock such as baffalos and horses numbered about 637,700 and the small-type livestock about 300,000, being 21 heads per 1 square kilometer in population density in case of the large type livestock.

Livestock depended in considerable part upon grasses of the natural grassland and partly upon natural grasses in upland farms and stems and leaves of crops after harvested. No forage was particularly produced. Accordingly, when grasses were withered from a prolonged arid season, stavation of a large number of livestock had been occurred as the result of the shortage of forage.

The raising of livestock was generally observed in the form of grazing in a primitive way to release livestock in the natural grassland. However, only baffalos were grazed in the day-time and brought back home in the night-time. Horses were grazed day and night.

Although natural grassland areas are located generally in a flat land, there are a mountainous natural grassland on the Mt. Lompo-Batang and on the range Latimodjong running from south to north in the west of the peninsula. The flat natural grasslands were situated in the central district between Mt, Lampo-Batang and the Lakes Tempe and Sidenren and a vast natural grassland deploying towards the eastern, western and northern directions of the Lakes Tempe and Sidenren.

These natural grasslands consisted of *Graminae, Cyperaceae* and a small number of *Leguminosae.* As main grasses of *Graminae*, they were *Rottboellia exaltata, Imperata cylindrica, Rhaphis aciculatus, Heteropogon contortus, Paspalum scrobiculatum, Themeda triander, Psuedopogonatherum tripicatum, Sorghum nitidum Pers. var. nitidum, Heteropogon triticeus, Ischaemum timorense* and *Zoysia tenuifolia.*

As the principal grassland types, there were the *Arang-Arang grassland* dominated by *Imperata cylindrica* and the long-grass type grassland abundant in *Heteropogon contortus, Rottboellia exaltata* and *Ischaemum timorense.* These natural grasslands are comparativly distant from the settlements and developed in the area where the intensivity of grazing was not so strong. On the contrary, the grasses in the area where the degrees of grazing was intensive were belonged to the family of *Eulalia, Rhaphis, Zoysia, Cynodon, Bothriocola* and *Panicum* species to present a natural grassland resistive to grazing (the grassland of these grasses is called the short-grass type grassland because of the abundance of the short-grass type species, and there is a long-grass type grassland which was migrated by *Ischaemum timorense* resistive to grazing.

As the above-mentioned grassland types were all the ones which were developed as the result of grazing, it is natural that there should be suceession in each type of the grassland. Firstly, although the natural grassland not subject to grazing should be the long-grass type grassland, there was seen the migration ot grasses resistive to grazing when the long-grass type species became withered by disturbances. With the rise of intensity of grazing, only grasses resistive strongly to grazing continued to remain so as to develop the *Arang-Arang grassland* dominated by *Imperata cylindrica*, the short-grass type grassland or the natural grassland dominated by *Ischemum timorenses.* Although these *Arang-Arang grassland* and short-grass type grassland were originated from the long-grass type grassland, the mutual relationship in the conversion into the two different plant successions was not made clear.

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Apluda mutica L.

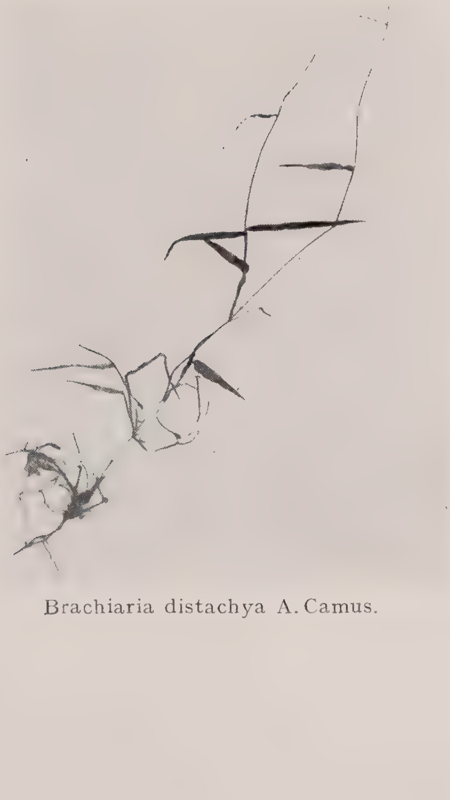
Arthraxon hispidus Makino.

Arundinella fuscata Nees.

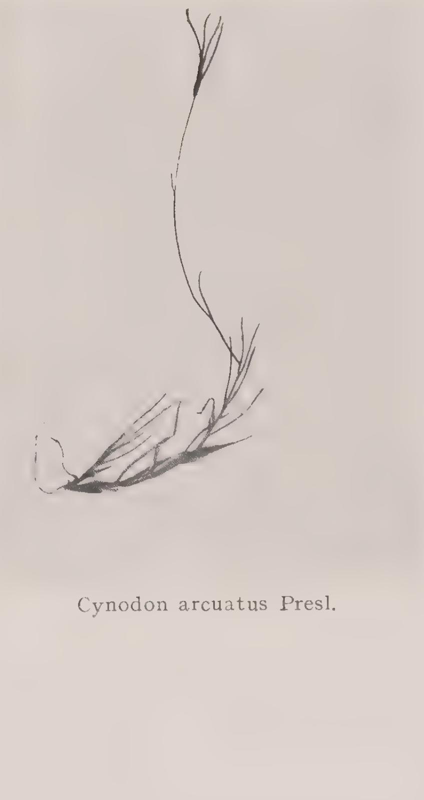
Arundinella setosa Trin.

Axonopus compresus Beauv.

Bothriocloa glabra A. Camus
var. perfectior Ohwi.



Brachiaria distachya A. Camus.



Cynodon arcuatus Presl.

Cynodon dactylon Pers.

Dactyloctenium aegyptium Richt.

Digitaria chinensis Hornem.

Dimeria arnithopoda Trim.

Eleusine indica Gaertn.

Eragrostis amabilis Wight et Arn.

Eragrostis diarrhena Steud.

Eragrostis nutans Nees.

Eriochloa procera Habbard.

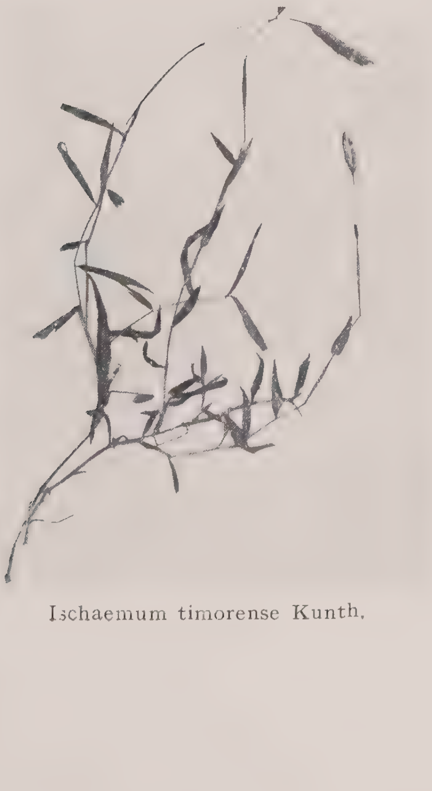
Eulalia amaura Ohwi.
(Polytrias amaura Henr.)

Eulalia leschenaultianna Ohwi.
(Andropogon lesch. Decne.)

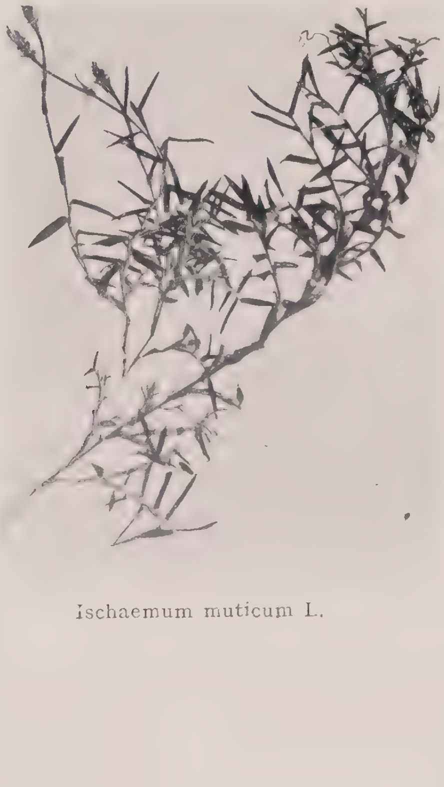
Heteropogon contortus Beauv.

Ischaemum aristatum L.

Ischaemum beccarii Hack.



Ischaemum timorense Kunth.



Ischaemum muticum L.

Leptochloa filiformii R. &. S.

Manisuris granularis Swartz.

Ottochloa nodosa Dandy.

Panicum indicum L.

Panicum suishaense Hayata.

Panicum plicatum Lamk.

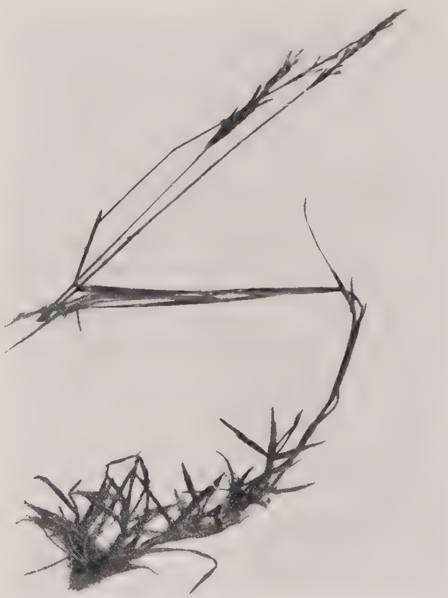
Paspalum distichum Linn.

Paspalum scrobiculatum Linn. Presl.

Paspalum Thumbergii Kunth.

Pognatherum crinitum Beauv.

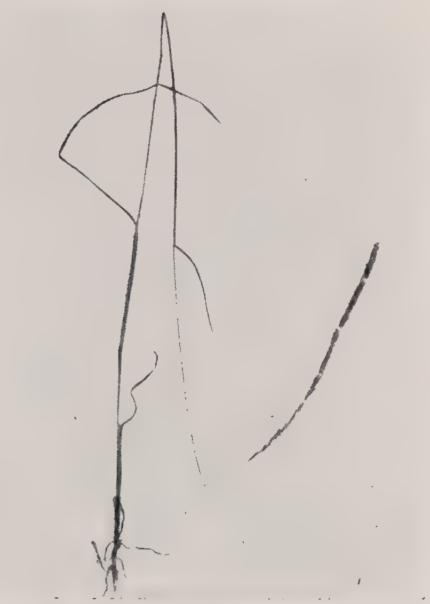
Pseudopogonatherum tripicatum Ohwi.
(Eulalia trispicata Henrard.)



Rhaphis aciculatus Honda.

Rottboellia exaltata L. f.

Sorghum nitidum Pers.
var. nitidum Ohwi.



Sporobolus elongatus R. Brown.

Urochloa paspalorden Prex.

Urochloa ambigua Presl.

Cantharospermum scarabaeoides Baill.

Cajanus Cajan Merr.

Desmodium heterocarpon D C.

Desmodium triflorum DC.

Desmodium racemosum DC.

Lourea obcordata (Pain) DC.

Tephrosia vestita Vogel.

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